DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Hydrogeological Landscapes of the Capertee and Coxs River Valleys

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Cover photo: Capertee Valley. Victoria Cull/DECCW.

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Contents

List of tables

List of figures

1. Salinity Basics

1.1 What is salinity?

Salinity refers to the accumulation of salts in the landscape. It is also a term that can be used to refer to saline water entering streams via base flow from groundwater and runoff from adjacent land. Land salinity can occur naturally. However, it typically occurs as a result of a change to the hydrologic balance within a catchment.

Salinity occurs when salts in the landscape are mobilised by surface water or groundwater. It results from changes in water use by vegetation. When the landscape water balance is altered, salinity can result.

Salt is naturally present in the Australian landscape and is stored within the landscape in soils, regolith materials, groundwater and rocks. Salts mobilised by changes in water balance and present in salinity processes are mainly derived from:

- cyclic salt – deposited as sea spray/atmospheric salt (i.e. in rainfall)
- aeolian salt – deposited with dust
- rock weathering – minerals weathering within rocks
- connate salt – from sedimentary rocks, where the salt has remained within the rock matrix from the time of deposition.

The dynamics of groundwater processes are important in the salinity story. A variety of systems and scenarios describe how water and salt move through the landscape. These systems should be understood in order to understand the risk and impacts of salinity in the landscape and to best target remediation.

Before European settlement, south-eastern Australian landscapes were characterised by:

- native vegetation communities which had a high perennial plant component (trees and grasses)
- native vegetation communities which had a high diversity of species
- soils which had surface organic matter layers (A_0 horizons).

After European settlement, land use led to significant changes. The landscape has been ‘annualised’ by farming and grazing systems of the past and present, meaning that most farming systems are now based on annual plants. This has simplified biodiversity of the landscape. Diverse woodlands and grasslands have been replaced by monocultures of crops, or simple mixtures of pasture species. This limits the timing and amount of water used by vegetation during the year and across climate cycles and events.

In rural areas where land use change has occurred (e.g. clearing of native vegetation), the water balance has altered and adjusted to a new balance. This can see salinity occurring at various points in the landscape. In urban situations, activities which impede water movement or increase water use (e.g. road or house construction) will further alter the landscape and salinity symptoms may also emerge.

Capillary rise (upward movement of water from the water table by molecular forces into the unsaturated soil above) often transports salts to the land surface, where they can adversely affect plant growth, infrastructure and dwellings.

Some plants or construction materials are more resistant to salts than others. In plants, this is referred to as ‘salt tolerance’ – such plants may indicate a salinity problem in the landscape. Some of the common landscape indications of salinity include:

- the presence of indicator plant species
- bare ground
- puffy soil
- salt crystals at the surface
- discharge of water
- dieback of vegetation that is less salt tolerant
- yellowing of crops or grassed areas
- stock congregating and licking a particular area of ground
- damage to infrastructure such as roads and houses
- dry scalds which occur when topsoils are lost through wind and water erosion, and saline and sodic subsoils are exposed to the surface

Discharge refers to groundwater that seeps into streams or on to the land surface. On the land, it is often expressed as areas of waterlogging. Evaporation of groundwater discharge may lead to salt sites

1.1.1 Concentration of salt

High water tables and capillary rise and evaporation lead to salts concentrating in the surface layers of the soil. This process can be intensified when vegetation and soil cover are lost and impediments to drainage occur due to salt and waterlogging impacts. This means that quite high levels of salt can accumulate at discharge sites in the landscape, even though the background levels of salt in groundwater and soils can be quite low. The amount of salt in the surface soils at discharge sites can vary dramatically over time. Seasonal and longer-term climatic influences will either dilute or concentrate salt. Plants have various levels of tolerance or ability to cope with salt concentration in the root zone.

1.1.2 Soil chemistry

The chemistry and behaviour of soils is modified by the addition of cations and anions in the landscape, which are often concentrated and mobilised in groundwater. There can be considerable variation in the type of salt at salt sites. The dominant cations are generally sodium and calcium, which combine with bicarbonate, chloride, sulfate and carbonate anions in varying proportions.

1.1.3 Waterlogging

Waterlogging leads to low levels of oxygen in the soil. This impacts on plant growth, health and survival. Plants have various levels of tolerance for, or ability to cope with, waterlogging and the resulting low levels of oxygen.

1.1.4 Vegetation impacts

The levels and combined effects of waterlogging and salinity will impact on a range of plants. Some plants can cope with high levels of salt, some with high levels of waterlogging. Few plants can cope with both high salt concentration and waterlogging. Common on-site effects include loss of production of agricultural species, decline of introduced pastures and native grasses, tree death and change in pasture health and composition.

Vegetation is a victim, as well as an indication, of salinity processes. Some plants can cope on a salt site. These plants commonly replace the original vegetation as it dies, colonising and dominating salt sites, and can be very useful indicators of saline conditions.

1.1.5 Sodicity

Sodicity refers to the percentage of exchangeable sodium cations held on the surface of clay particles. The greater the proportion of sodium in the total exchangeable cations, the more sodic the soil (Anderson et al. 1998).

High sodicity adversely affects soil stability, plant growth and land use. Upon wetting, the separation and expansion of clay particles results in soil dispersion, soil swelling and reduced soil permeability. As the soil dries, the clay particles fall out of suspension and tend to plug soil pores. The soil solidifies into an almost concrete-like mass with little or no structure.

Sodic soils can have the following characteristics (Hazelton and Murphy 2016):

- very severe surface crusting
- very low infiltration and hydraulic conductivity
- very hard, dense subsoils
- high susceptibility to gully erosion
- high susceptibility to tunnel erosion.

How sodicity differs from salinity

In many ways, exchangeable sodium has the opposite effect to salinity on soils. Salinity is the concentration of soluble salts in water and soil, assessed by measuring electrical conductivity (EC). A highly saline soil (high EC) often results in clay platelets flocculating (clumping together). An example of this is where cloudy river water becomes crystal clear when it meets seawater. The highly saline marine environment causes suspended sediment to flocculate and quickly settle to the bottom. Flocculation is the opposite of dispersion. In contrast to sodic soils, highly saline soils tend to be more permeable.

How sodicity and salinity interact

Soil dispersion not only reduces the amount of water entering the soil, but also affects the soil hydraulic conductivity. This is the rate at which water flows through soil. For instance, soils with good structure will contain many macropores, cracks, and fissures which allow the relatively rapid flow of water through the soil. When sodium-induced soil dispersion causes loss of soil structure, the hydraulic conductivity is also reduced.

The reduced hydraulic conductivity caused by sodicity affects movement of water and salt through and on top of the soil. Sodic soils are often found in the same areas as saline outbreaks. Salinity leads to loss of groundcover, exposing the underlying sodic soil materials. Once exposed, these soils readily erode, degrading land and polluting watercourses with suspended sediment, including saline sediments. Large bare and eroded areas are often a sign of salinity and sodicity acting in tandem.

1.1.6 Erosion

In sloping landscapes, salinity impacts on, and is impacted by, gully and sheet erosion. It causes loss of groundcover and intensifies erosion.

Salts concentrated close to the soil surface frequently cause ‘puffiness’, which makes the soil more susceptible to erosion.

When gullies develop they may intersect the water table. If the groundwater is saline, the discharge of this water in the gullies makes it difficult to revegetate naturally or with remedial action. This results in further erosion and input of saline groundwater to the gully for longer periods and the gully degrades further.

In sodic landscapes, rill and gully erosion commonly result from the reduced drainage capacity of sodic stratigraphic units. There is strong lateral movement along the stratigraphic units which increases the volume of water and salts impacting on eroded slopes or benches.

1.1.7 Impacts on infrastructure

Salinity processes impact on a range of infrastructure through waterlogging, salt concentration and growth of salt crystals in porous material.

Much infrastructure is designed and constructed to allow for short-term inundation or is waterproof from the top down. However, salinity impacts are more likely to result from long periods of waterlogging, upward pressure from groundwater systems or intermittent wetting and drying.

Salinity compromises the strength and resilience of many metals used in infrastructure, predominantly through increased oxidation (mostly rust).

Salt can enter porous media (bricks and pavers) through capillary rise, with subsequent evaporation of the salt-bearing solution precipitating salt crystals. As the crystals grow they exert physical pressure on the media and cause it to disintegrate.

1.1.8 Off-site impacts

The effects of changes in vegetation and land use are not always evident where those changes occur. Off-site impacts include:

- subcatchment impacts where cause and effect are separated by distance and time
- water quality of streams, rivers and water bodies
- catchment impact by redistribution of load, and the issue of water quality versus water quantity.

It is common for discharge areas to be affected by recharge over considerable areas distant from the site. Recharge refers to water that percolates through to groundwater. Increased recharge can lead to rising water tables and mobilise salt stored in the soil. These changes can take time to be expressed in the landscape. The impact on a catchment of increased recharge will be determined by the:

- groundwater storage capacity of the catchment
- porosity of the regolith material and the related rate of groundwater flow within the catchment.

1.2 Salinity expression

Aside from land salinity (also referred to as dryland salinity or salt land), salt is mobilised within catchments and impacts on the water quality of streams and rivers. Changes in salt concentration relate to the total amount of salt mobilised, groundwater salinity levels, flow rates in the river and dilution from rainfall. These changes are commonly expressed in two ways:

- as ‘pulses’ of water with a high(er) salt concentration moving down-stream over a comparatively short time (hours or days)
- as streams with consistently high salt concentrations which do not vary significantly with variation in stream flow.

1.2.1 Land salinity

Land salinity results from high water tables and concentration of salt due to evaporation at the soil surface. This impacts on land assets by damaging infrastructure, ecosystems, vegetation, soil health and agricultural production. In the Capertee Valley and only rarely in the Coxs River Valley, land salinity is expressed as scalds (bare soil surfaces), usually low in the landscape and often actively eroding (Figure 1).

Figure 1 Scalded salt land in foreground (Nile HGL) beside Umbiella Creek, Capertee Valley, looking south
(Photo: Victoria Cull/DECCW)

1.2.2 Salt load

Salt load is a measure of the dissolved load of salt in a stream and is expressed as a mass per unit time (e.g. tonnes per day). High salt loads can result from low volumes of water with high concentrations of salt, or high volumes of water with low concentrations of salt. Salt loads vary because of salt distribution and redistribution in the landscape. Streams and rivers move diffuse salt sources in upland and slope areas to areas further downstream in catchments (Figure 2). Extraction of water from rivers and streams for irrigation redistributes some of this salt load into the soil. Salt loads are also redistributed across wetlands and flood plains during floods, particularly in non-regulated streams. Floods also flush the near-surface soil layers, leaching salts further into the regolith.

In the Capertee Valley, areas with salt load impacts are low lying, with good connection to streams. They have landform features such as depressions which function as concentration and evaporation areas. Revegetation of these specific areas will help reduce salt load.

Figure 2 Salt efflorescence on the bank of the Nile Creek, Capertee Valley (Photo: Luke Taylor/DECCW)

1.2.3 Stream EC (water quality)

Stream salinity integrates landscape processes within a catchment and is a primary water quality indicator. In a salinity context, water quality primarily relates to the concentration of dissolved salts in the water, measured in terms of its EC, which is a function of the total concentration of dissolved salts. EC is measured in units of microSiemens per centimetre (µS/cm) at 25ºC and is easily measured in-stream with a conductivity meter. High salinity levels in inland water systems can harm the ecological function of riverine environments and wetland systems. They also limit domestic, recreational, industrial and agricultural water use.

1.2.4 Managing salinity processes

Accurate tailoring of appropriate land use for salinity management should be a core objective for natural resource and land managers. This requires a technique which matches appropriate land use to the most suitable locations to obtain optimal management results.

The magnitude of change in recharge due to land management practices is a critical factor in the management of salinity. Salinity processes are driven by the climate, the water use characteristics of the vegetation, and the hydrogeological characteristics of the landscape. Actions which affect the way water is used by vegetation or stored in the soil will impact on recharge and runoff.

Salinity processes are usually diffuse across a landscape, so action is needed over a large proportion of a catchment to have a significant impact. The design of management actions must allow for both continuous and episodic recharge patterns. Patterns of salinity occurrence and intensity are related to annual and decadal climatic cycles (e.g. droughts). Design of land management actions should consider extreme events affecting recharge and discharge.

Catchment-scale salinity management also must consider the surface hydrology of the landscape, including sources and magnitude of both saline inputs and fresh inputs to the catchment hydrologic system.

2. Introduction to the Capertee and Coxs River Valleys

2.1 Background

This document and the accompanying maps deal with the nature and consequences of salinity in the Capertee Valley and the Coxs River Valley. They have been produced by the NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI). The original project was carried out for the Hawkesbury-Nepean Management Authority (HNCMA), with funding provided under the Salinity Strategy Enhancement Program. The maps and document result from a series of salinity projects OEH is undertaking to better understand how dryland salinity manifests in the landscape and how salinity may be best managed.

The Natural Heritage Trust (NLWRA 2001) estimated that the threat from salinity will increase across Australia from ~5.7 million ha in 2000 to ~17 million ha by 2050. Consequently, the targeting of beneficial land use activity to control dryland salinity at specific locations is paramount for appropriate salinity management. Variation in climate, soil characteristics, hydrology and salt storage occur down to the property scale. Accordingly, a landscape assessment system is required that enables land use recommendations to be developed at this scale.

HGLs have been developed to characterise and manage the quality and distribution of water on the surface of the landscape and in the shallow sub-surface. HGLs build on the existing Groundwater Flow System (GFS) framework, developed largely for salinity management (Coram 1998, Coram et al. 2000, Walker et al. 2003). The framework was developed using existing geological data, supplemented by hydrological and topographic data. GFS map units subdivide the landscape into areas with similar groundwater flow and salinity characteristics.

The HGL concept further develops and enhances GFS by including information about landforms, regolith (including soils) and elements of structural geology (Wilford et al. 2008, Wilford et al. 2010). The 'hydrogeological' term highlights the important components of water, geology and regolith, whereas 'landscape' represents the significant influence of landforms, regolith and soils on the hydrological regime. Similar frameworks in North America have used a landscape approach to delineate hydrological systems for managing groundwater and surface water resources (Winter 2001). HGL units accordingly integrate information on lithology, bedrock structure, regolith (including soils), landforms and hydrologic systems. The HGL unit (or area) represents a landscape component that captures many hydrological parameters, including water flow (surface, shallow lateral and groundwater flow), storage and quality. It can be used to support a range of natural resource management (NRM) applications, including assessment and management of land salinisation.

The HGL structure brings understanding of how differences in salinity are expressed across the landscape. An HGL spatially differentiates areas with similar salt stores and pathways for salt mobilisation. The process of delineating an HGL relies on integrating a number of causative factors: geology, soils, slope, regolith thickness and climate; an understanding of the different modes of salinity development; and the impacts of salinity within landscapes (land salinity, salt load and salt concentration in streams due to salt contributions from base flow and runoff). Information sources such as soil landscape maps, site characterisation, salinity occurrence maps, hydrogeological data, surface water and groundwater data are incorporated into standardised unit descriptions.

The HGL unit descriptions give a framework to spatially define salinity management areas and recommend how best to manage and prioritise these landscapes. In the Capertee and Coxs River Valleys, 24 HGLs have been defined, each with unique salinity situations (salinity management areas) which require tailored management solutions involving specific management actions.

The project relied on a number of different disciplines and skill sets to develop an integrated understanding of the landscape. The following groups were involved in the project:

- OEH/DPI Staff:
    - Landscape Management Technical Group – HGL conceptualisation, land management
    - Spatial Products Unit – geographical information system (GIS) support
    - Assessment Team – site characterisation, soil properties, mapping, HGL unit definition.
- University of Canberra – regolith understanding, HGL conceptualisation, geology
- Former HNCMA staff - local information, training and communication.

Over the course of the project, a number of field days were held, as well as discussions and meetings with HNCMA staff and the Capertee Valley Landcare Group. This incorporated local knowledge into the HGL templates and in return gave the HNCMA staff and landholders an understanding of how an HGL functions.

Terminology specific to soil, regolith and geology is used extensively throughout this document. The following glossaries are recommended for further information on the terms used:

- soil – Houghton and Charman (1986); Isbell (2002); Morse et al. (1982); NCST (2009); Northcote (1979); and Stace et al. (1968)
- regolith – Eggleton (2001)
- geology – Neuendorf et al. (2011).

A map showing the distribution of the 16 Capertee Valley HGLs and 8 Coxs River Valley HGLs, and a summary table of HGL attributes, are found in Appendix A.

The detailed unit descriptions for the 24 HGLs in both valleys are found in Appendix B.

Data sources are described in Appendix D and an overview of the attribute table attached to the HGL dataset is given in Appendix E.

2.2 Regional setting

2.2.1 Location

The Capertee and Coxs River Valley subcatchments lie in the north-western portion of the Hawkesbury-Nepean River catchment (Figure 3). The mapped area encompasses the towns and localities of Capertee, Glen Davis, Glen Alice, Lithgow, Hartley, Hampton, Megalong Valley, Marrangaroo, Lidsdale and Wallerawang. The Capertee Valley subcatchment occupies close to 100 km2 and the Coxs River Valley subcatchment covers about 90 km^2.

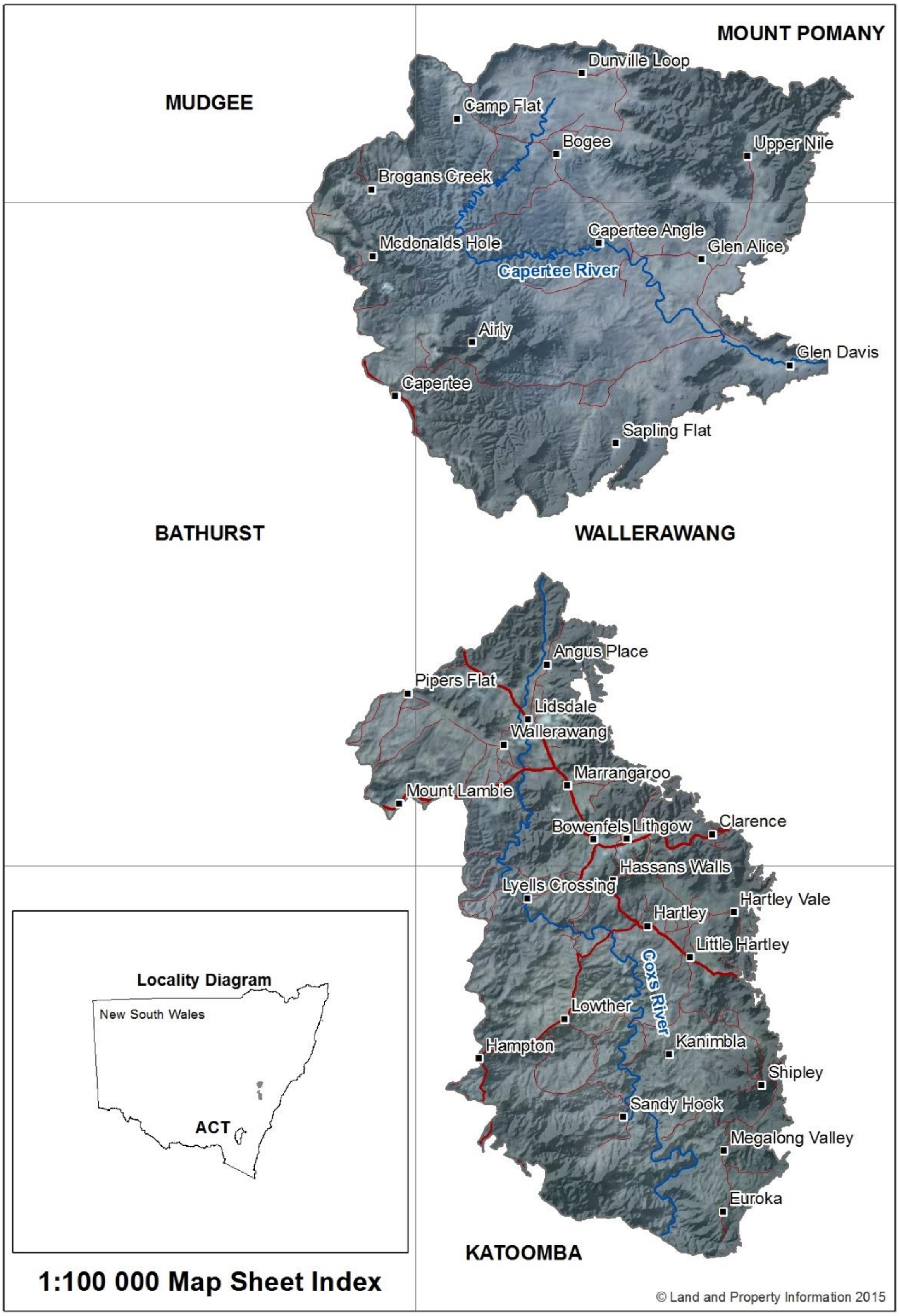

Figure 3 Location map of the Capertee (top) and Coxs River (bottom) Valley study areas showing 1:100 000 map sheet coverage

2.2.2 Geology of the Capertee and Coxs River Valleys

Rocks within the Capertee and Coxs River Valleys date from the mid to late Paleozoic and early Mesozoic eras and are between 410 and 230 million years old. These rocks occur on the edge of the Sydney Basin and consist of early Permian to middle Triassic marine, deltaic and fluvial sediments.

The geological units of the Capertee area have horizontal bedding planes (Figure 4). Most structures in the Lachlan Fold Belt trend north-south, as is evident in the Lithgow area, and this is perpendicular to the direction of extension during the Silurian to Mid-Devonian (Scheibner 1999). The Lachlan Fold Belt lithologies are extensive south of the Lithgow area and are characterised by Devonian conglomerates and granites from the Nowra and Shoalhaven Groups.

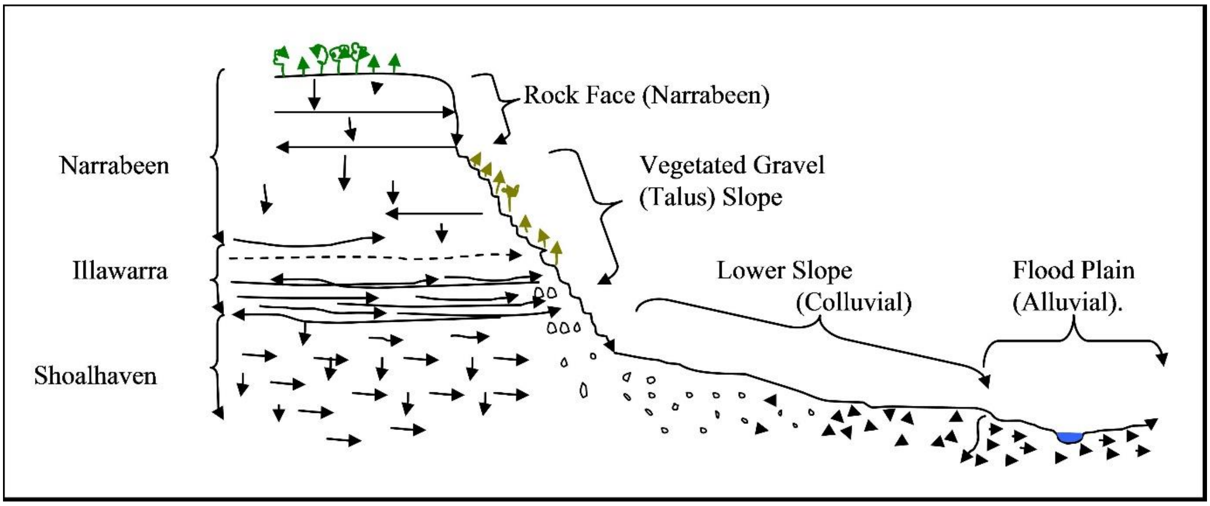

Figure 4 Schematic diagram of stratigraphy in the Capertee Valley (Moore et al. 2010)

The landscape has been significantly eroded (exposing a large section of the Triassic sequence) to form broad and deep valleys with large vertical sandstone cliffs, and some pagoda formations around Lithgow. An older Devonian basement of tilted and deformed igneous, metamorphic and sedimentary rocks is also present and outcrops in the Wolgan and Capertee Valleys. Carboniferous rocks associated with the Tarana Granite, which underlie the western edge of the Sydney Basin, may be seen in the Coxs River Valley and the Wolgan Valley. Some minor basaltic caps, which are remnants of extensive Cenozoic flows, are also found.

Broad geological groupings for the Capertee and Coxs River Valley areas are shown in Figure 5.

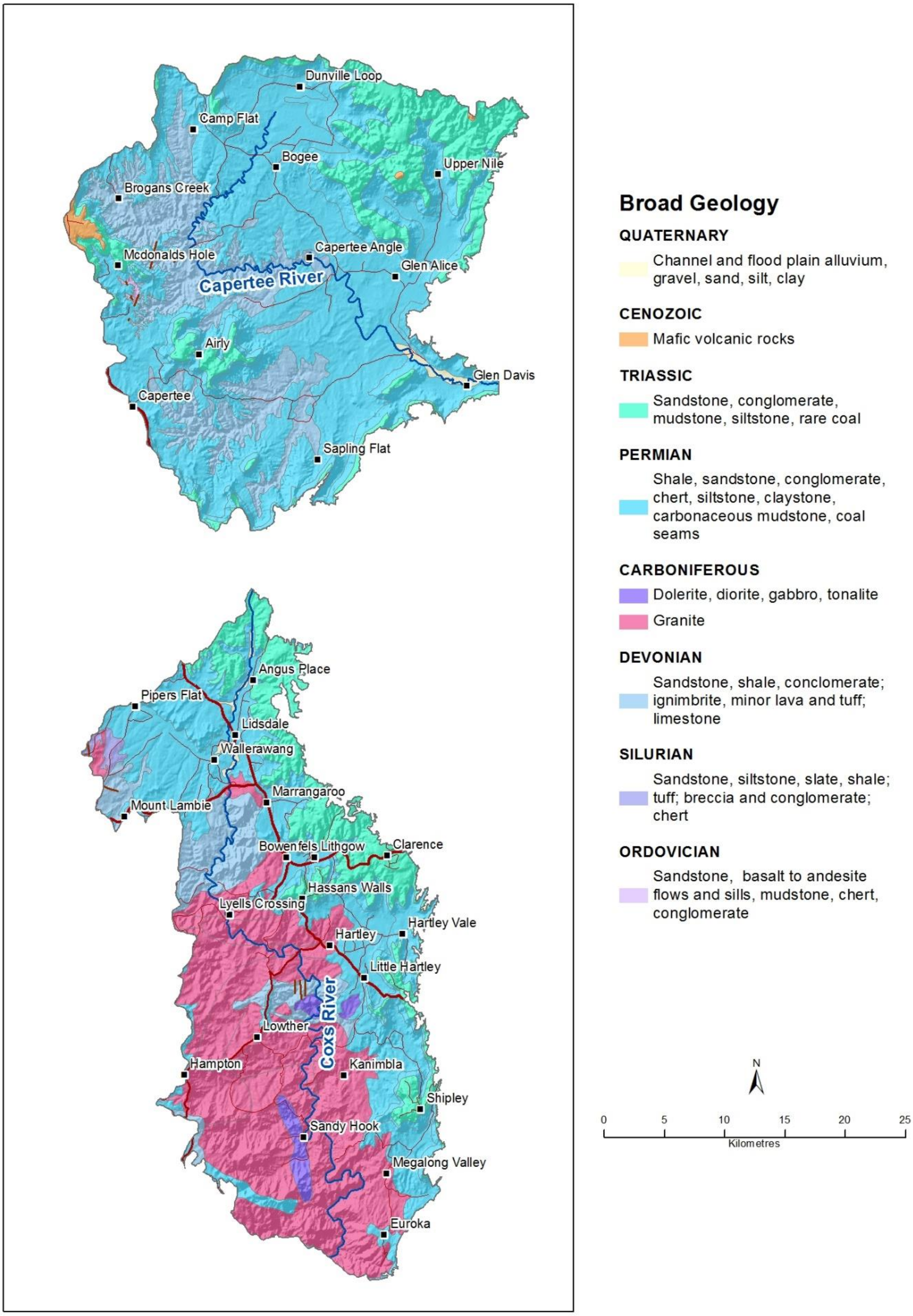

Figure 5 Geological groupings across the Capertee and Coxs River Valleys

Broad stratigraphic units present in the Capertee and Coxs River Valleys

Siluro-Devonian

Kandos Group – consists of tilted and deformed igneous (felsic volcanic and volcaniclastic) and metamorphic rocks (quartzite, schist, phyllite) and mixed sediments (limestone, shale, sandstone).

Carboniferous

Bathurst-type Granites (Tarana Granite) – the granites of this unit at Lithgow and in the Wolgan Valley consist of pink porphyritic granites, adamellites and granodiorites (Knutson and Flood 1988). This unit is scattered along the north-eastern margin of the Lachlan Fold Belt, cutting across structural zones and predominantly occurring in zones of crustal weakness (Scheibner and Basden 1998).

Permo-Triassic

Shoalhaven Group – dominantly marine and consists of siltstone, sandstone, and minor conglomerate (Herbert and Helby 1980). It unconformably overlies the Late Carboniferous granite and Late Devonian folded sediments of the Lambie Group (Herbert and Helby 1980).

Illawarra Coal Measures – subdivided into several constituent units (Geoscience Australia 2019), including the Nile, Cullen Bullen, Charbon and Wallerawang subgroups, and the Lithgow Coal and the Irondale Coal Formations (Australian Stratigraphic Database, 2015). The Nile Subgroup predominantly consists of deltaic sandstone and top-delta coals, and the Charbon Subgroup predominantly consists of fluvial point bar sandstone, floodplain siltstone, claystone and coal (Herbert and Helby 1980). The Cullen Bullen Subgroup is predominately coarse-grained pebbly sandstone and coal.

Narrabeen Group – predominantly sandstone, with some claystone and shale. The Grose Subgroup of the Narrabeen Group forms the large cliffs in both the Capertee and Coxs River Valleys while the lower section of the unit – the Caley Formation – is largely obscured by the vegetated talus. The Narrabeen Group represents the top of the landscape in these valley systems, as the more recent Hawkesbury Sandstone unit has not been deposited here. It begins to the east of these valleys and extends to the coast.

The Permo-Triassic stratigraphy for the western Blue Mountains is summarised in Table 1.

Cenozoic

Basalts – consist of basaltic lava flows and dykes distributed in isolated locations as remnant caps or valley flows (such as Brogan View HGL in the Capertee Valley).

Quaternary

Unconsolidated sediments – typically found throughout the Capertee and Coxs River Valleys, although usually associated with current streams.

Table 1 Permo-Triassic stratigraphic nomenclature for the Western Blue Mountains (Source: Herbert and Helby 1980, Yoo et al. 2001, Geoscience Australia 2019)

PERIOD	GROUP	SUBGROUP	FORMATION	MEMBER	LITHOLOGY
TRIASSIC	Wianamatta Group		Ashfield Shale		Dark grey shale with thin sandstone bands
			Mittagong Formation		Interbedded shale and sandstone
			Hawkesbury Sandstone		Quartzose sandstone, massive and cross-bedded
	Narrabeen Group	Gosford Subgroup	Burralow Formation		Shale/sandstone laminite
		Grose Subgroup	Banks Wall Sandstone		Quartzose sandstone, friable
			Mount York Claystone		Red-brown claystone, sandstone
			Burra-Moko Head Sandstone		Sandstone
			Caley Formation	Hartley Vale Claystone Member	Claystone, shale, fine-grained sandstone
PERMIAN				Victoria Pass Claystone Member	Claystone, shale
				Clwydd Sandstone Member	Quartz-lithic sandstone
				Beauchamp Falls Shale Member	Claystone, shale, sandstone
	Illawarra Coal Measures	Wallerawang Subgroup	Farmers Creek Formation	Katoomba Coal Measures	Claystone, sandstone/shale, laminite, sandstone, torbanite, conglomerate, coal
				Burragorang Claystone Member	
				Middle River Coal Member	
			Angus Place Sandstone		Quartz-lithic sandstone
			Glen Davis Formation		Coal, carbonaceous claystone, claystone and siltstone and sandstone
			Newnes Formation		Lithic sandstone, siltstone, claystone
			Irondale Coal		Bright coal, generally brighter and thicker towards the top; two or three stone layers
			Lithgow Coal		Dull coal with minor bright layers; a few thin carbonaceous or tuffaceous claystone layers in the upper half
		Charbon Subgroup			Delta plain sediments with marine incursions: sandstone, siltstone, claystone, coal
		Cullen Bullen Subgroup	Marrangaroo Conglomerate		Sandstone, conglomerate, fine siltstone
		Nile Subgroup	Gundangaroo Formation		Coal, carbonaceous shale, shale, sandstone
			Coorongooba Creek Sandstone		Medium lithic sandstone, minor conglomerate, fossil wood
			Mount Marsden Claystone		Dolomite, limestone, claystone, chert, conglomerate (silicified), fine lithic sandstone
	Shoalhaven Group		Berry Siltstone		Micaceous siltstone, limestone, minor evaporites
		Conjola Subgroup	Snapper Point Formation		Lithic sandstone, basal conglomerate, minor shale

2.2.3 Physiography

The terrain of the Capertee Valley is highly variable and includes the world's second largest canyon. Contained within the Coxs River Valley subcatchment are mountain ranges, gorges, escarpment, canyon valleys, rolling rises and hills, extensive areas of relict floodplain, current floodplain, swamplands and plateaus. The complex nature of the terrain has implications on the way salt is stored and mobilised within the landscape.

The areas can be broadly described as two physiographic regions (Bathurst Tablelands and Hawkesbury-Shoalhaven Plateaus), as set out by Pain et al. (2011) in the Physiographic Regions of Australia (Figure 6). Each region is a geomorphic subdivision with internally consistent landform morphology and inferred landscape process origins, as determined from the Shuttle Radar Terrain Mission digital elevation model (Gallant et al. 2011).

The Bathurst Tablelands physiographic region dominates the Capertee River Valley. It is characterised by granitic and basaltic tablelands and minor lowlands.

The Hawkesbury-Shoalhaven Plateaus physiographic region makes up the majority of the Coxs River Valley. It comprises deeply dissected sandstone plateaus.

Capertee Valley subcatchment

The Capertee Valley is defined by encircling precipitous mountainous terrain which displays complicated geological stratigraphy along the canyon wall face. These rocks underlie the Triassic deposits of the Narrabeen Sandstone and overlie the earlier Permian deposits of the Shoalhaven Group. In the north-west of the map sheet, the landform is dominated by a hard ridge of Narrabeen Group, which defines the western Hawkesbury-Nepean/Central West Catchment divide and forms the cliff tops and plateaus of the canyon valley. Some forms part of the Great Dividing Range. The highest point on the map sheet is Mount Marsden, reaching an elevation of 1040 m. Included with the ranges are some elevated plateau and rocky escarpments. These ranges generally contain fresh water flow.

Within the valley the drainage flows over steep walls, footslopes, low rolling rises and minor swamps and occasional outcropping rock structures. To the south and west of Mount Marsden, Devonian shale deposits characterise a stratigraphy of vertically orientated bedding planes which sustain a regionally distinguishable community of shrubby forest. The south-east escarpment falls away to the north, into a constricting diversion channel of the canyon. It consists of deeply eroded Shoalhaven Group sediments and well-formed drainage channel scars around hills within the central valley floor and through colluvial deposits and active fluvial deposits where base flow surfaces. This is an area of accumulation of flows and has high salt stores and brackish water distribution.

In the north-east the Capertee River has incised a precipitous gorge through the Narrabeen Group deposits and into the underlying shale sediments and coal seam stratigraphy. The country contributing the flows into the gorge is potentially unstable and has the erosional capacity to release large volumes of water with saline and sodic properties from the sulfur-enriched coal seam sediments.

The eastern zone of the Capertee Valley study area consists of a ridge system, extending out from the Narrabeen Group cap. This area is associated with geological units from the Permo-Triassic, such as sandstones, conglomerates, coal seams and metasediments. The ridge system trends east-west, with a varying stratigraphy of uniform to mixed sedimentary units, such as sandstones and shales on the crests of the hills and mixtures of interbedded coal seams, conglomerates and mixed sediments on the slopes. Marine sediments are present at the base of this ridge system. In the south-central valley, rolling low hills and rises dominate the landscape. These trend in a west-east direction and are typically formed on metasedimentary units.

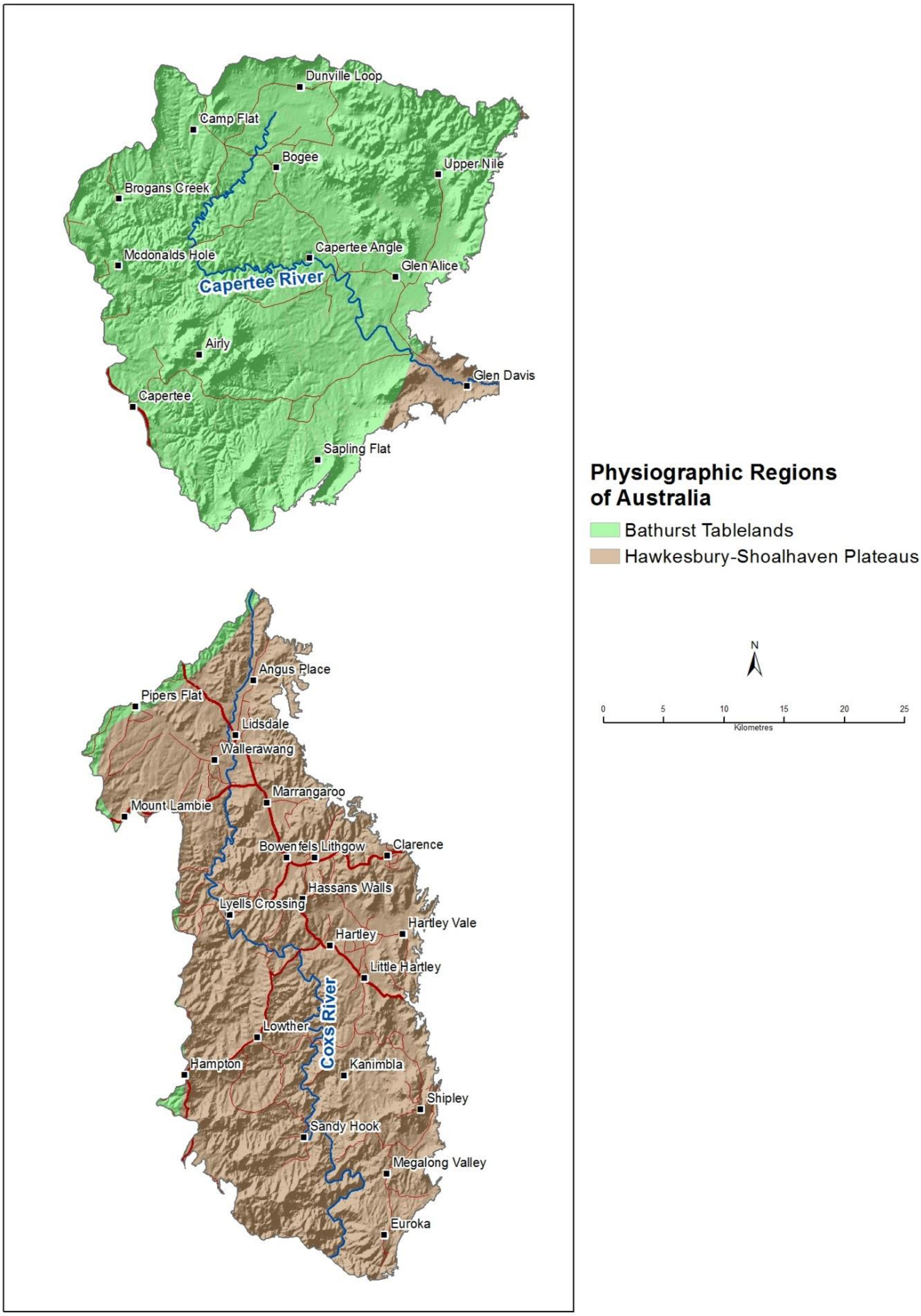

Figure 6 Distribution of Australian physiographic regions across the Capertee (top) and Coxs River (bottom) Valleys
(Source: Pain et al. 2011)

The northern section of this metasedimentary landscape has higher local relief than the south, with hills and low hills the dominant features. Landscapes further south of this area tend towards a higher relief, with the pagoda sandstone features of the Narrabeen conglomerate and granites of the Lithgow area. The salt store in this flatter area is of moderate occurrence and needs HGL consideration.

Coxs River Valley subcatchment

The Coxs River subcatchment has mainly formed on fluvial sediments and metasediments. Much of this area is dominated by low hills, rises and extensive alluvial plains.

There is a series of ridge systems extending outwards from the sandstone plateau, which features in much of the central Hawkesbury-Nepean catchment area. The low hills and rises on the valley floors are associated with mixed sediments. The flood plains of the Capertee, Coxs and Hawkesbury Rivers and their tributaries consist of recent alluvial sediments. Either side of the recent alluvium are extensive areas of ancient Shoalhaven Group sediments. These areas typically have a stepped appearance and minor potential for salinity development.

2.2.4 Climate

The general trend across the Hawkesbury-Nepean Catchment is for variation in climate from the west to the east, mostly attributed to the shape of the landscape. The eastern Low Relief Coastal Zone has a climate influenced primarily by interaction with the ocean, limiting maximum temperatures in summer, while the western area has hot summer temperatures. Rainfall in the eastern area is higher and more variable than the west, which has a much drier winter. There are warmer winter temperatures across the eastern zone than elsewhere in the Hawkesbury-Nepean area.

The two subcatchments of the study area fall within the western area of the Hawkesbury-Nepean Catchment. This Blue Mountains Zone has an orographically driven climate and is wetter than the neighbouring Low Relief Coastal Zone and South-Eastern Highlands. It also has the coldest temperatures in the catchment, in both summer and winter (Table 2 and Figure 7).

The rainfall pattern within the Coxs River Valley decreases from the wetter ridgelines on the elevated east and west subcatchment boundaries to lower rainfall on the valley bottom. The rainfall on the eastern subcatchment escarpment is slightly higher (annual precipitation reaches 1300 mm in the Blue Mountains National Park) compared with the western escarpment (around Jenolan State Forest), where the annual rainfall reaches 1100 mm. The average annual rainfall in the Coxs River Valley ranges from 770 to 900 mm.

The Capertee Valley is slightly drier and more uniform in precipitation, with maximum annual rainfall on the subcatchment edges reaching 830 mm and averages on the valley bottom ranging from 650 to 700 mm.

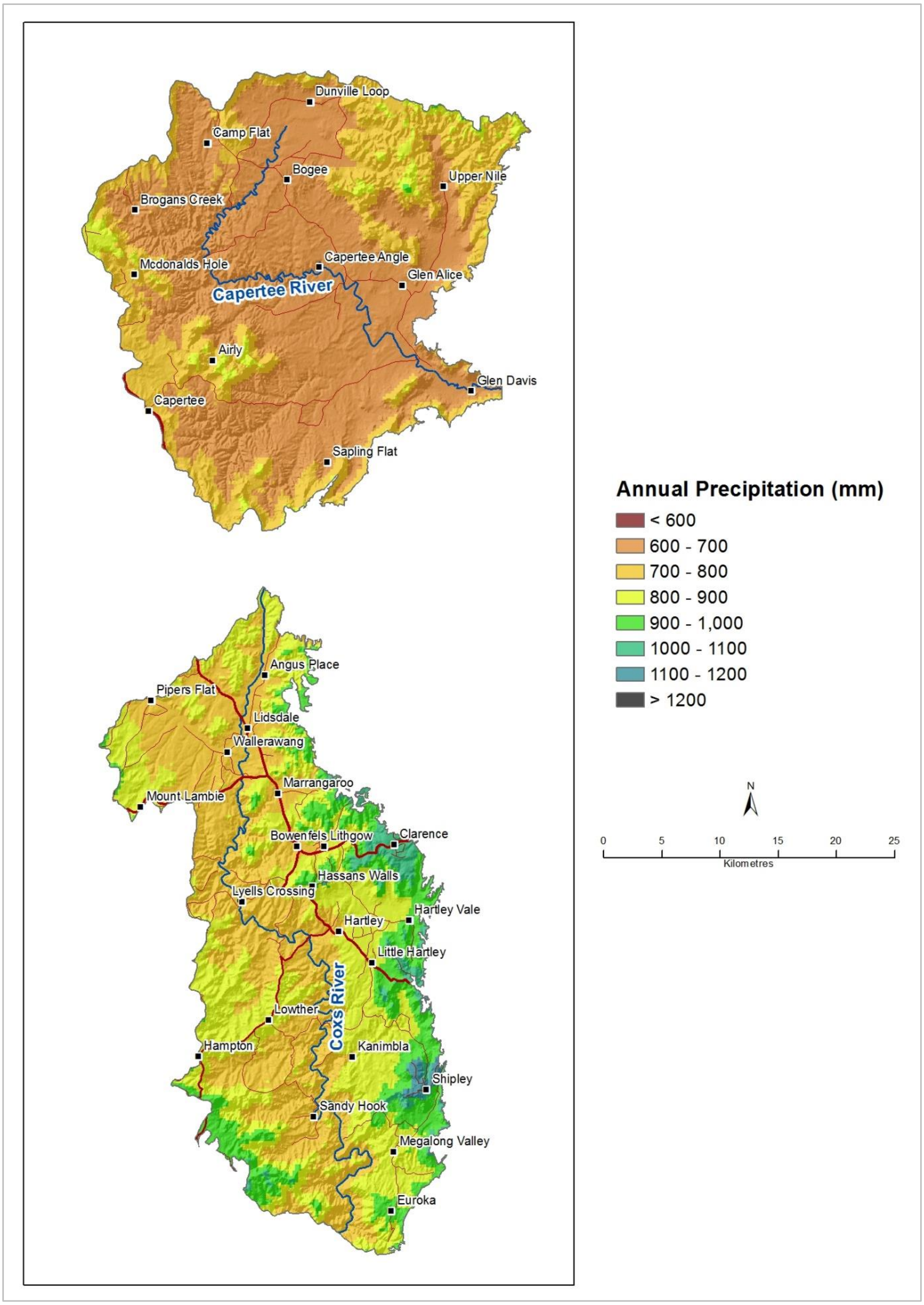

Figure 7 Annual rainfall distribution for the Capertee and Coxs River Valleys (DECCW 2009)

Table 2 Mean annual climate statistics for selected locations around the Capertee and Coxs River Valleys (BoM 2016)

	Bureau of Meteorology Sites			
	MOUNT BOYCE AWS (063292)	**OBERON (SPRINGBANK) (063063)**	**NULLO MOUNTAIN AWS (062100)**	**KATOOMBA (MURRI ST) (063039)**
Maximum temperature (°C)	17.0	16.9	16.6	16.8
Minimum temperature (°C)	8.0	5.2	8.0	8.0
Rainfall (mm)	967.5	840.5	940.2	1404.7
Number of rain days	102.1	84.8	89.6	107.8
Period of Record	1994–2016	1888–2016	1994–2016	1907–2016

2.2.5 Regolith

Regolith is typically defined as all the material between fresh bedrock and the land surface (Scott and Pain 2008). It includes all soil horizons, alluvial, colluvial and aeolian material, as well as weathered bedrock and any indurated or hardened layers in the landscape.

The nature and distribution of regolith materials is strongly influenced by the following (Scott and Pain 2008, Taylor and Eggleton 2001):

- **Parent material** – the chemistry of the parent material influences the chemistry of the regolith materials. The weathering pathways and products derived from parent material can be predicted if the mineralogical make-up of the parent material is known.
- **Climate** – temperature and rainfall both have a major impact on regolith development. However, rainfall is particularly important to form regolith materials. Water is the primary agent in the weathering process, therefore as rainfall increases, so too do weathering rates. Areas with higher temperatures, in general, experience higher weathering rates than those with the same rainfall and lower temperatures.
- **Topography** – this influences erosion across the landscape. Areas with a lower gradient commonly have lower erosion rates than those with a higher gradient.
- **Biota** – biological activity in the regolith can consist of anything from termite to marsupial activity. This type of activity can influence the structure of regolith materials and the rate at which they develop. A higher occurrence of biological activity may result in an increased rate of regolith development.
- **Time** – materials subjected to longer weathering processes are typically more weathered than those subjected to weathering for a shorter period.

While there is no published regolith map for the Capertee and Coxs River Valleys, the distribution and nature of regolith materials in this area can be extrapolated using the existing data on parent material, climate, topography, biota and time. An understanding of regolith materials and their distribution is important when examining salt store availability and distribution across any given landscape. The Hydrogeological Landscapes map for these areas provides a basis to understand regolith distribution and where salts are stored in the landscape

2.2.6 Soil

The physical and chemical makeup up of soil is strongly influenced by the parent material. This may predominantly comprise primary in-situ bedrock, or secondary transported material (Gray and Murphy 1999). Climate, topography, organic matter and time are other key factors in soil formation.

The original soil landscape products for both Capertee and Coxs River are covered in Soil Landscapes of the Wallerawang 1:100 000 map sheet (King 1993) and the Katoomba 1:100 000 map sheet (King 1994). These documents have been updated in the Soil and Land Resources of the Hawkesbury-Nepean Catchment (DECC 2008), which is used as the primary soil reference for this report. Soil landscape linework can be accessed via eSPADE (http://espade.environment.nsw.gov.au/), a Google Maps™ based information system that allows free, easy access to a wealth of soil and land information across NSW on both desktop and mobile devices. The soil classification system used for the HGL descriptions is the Australian Soil Classification (Isbell 2002), with Great Soil Groups (Stace et al. 1968) provided in brackets.

Soils in the Capertee and Coxs River Valleys (Figure 8) are highly variable and range from shallow, lithic and stony soils on the cliffs, plateaus, scarps, and crests, to more clay rich, texture contrast and alluvial soils on the lower slopes and valley flats. Typically, Earthy Sands, stony Lithosols, Siliceous Sands, Yellow Earths and Red Earths are found on cliffs, talus and crests; Yellow Podzolic Soils and Soloths on midslopes; Red Podzolic Soils, Soloths and Yellow Solodic Soils on lower slopes; and Alluvial Soils, Prairie Soils, Soloths and Alluvial Sands on floodplains and in drainage lines. This is a general trend which applies to many lithologies. Distinctive features of the soils of the Capertee and Coxs River Valleys are:

- highly erodible
- low fertility
- strongly acid topsoils
- stoniness
- aluminium toxicity
- low wet-bearing strength.

Soils are an important influence on salinity: they can act as a salinity store, a blockage or a source of saline recharge. In areas of minimal soil material (e.g. Lithosols), such as on top of cliffs and ridges (e.g. Genowlan Mountain HGL and Hartley HGL), little or no salt is stored in soil material. Conversely, in areas of deeper clay soils, such as on the valley floor (e.g. Glen Alice HGL), the potential to store salts increases.

The generalised relative assemblage of the soil layers for the Capertee and Coxs River Valleys is shown in Figure 9. The soil profile structure influences the delivery of salts in the landscape and is significant for development of saline land. Texture contrast soils provide a vertical impediment to movement of water: water often flows along the boundary between the lighter textured A horizon and the clayey B horizon. Discharge sites are often at the break of slope, where saline scalds may form.

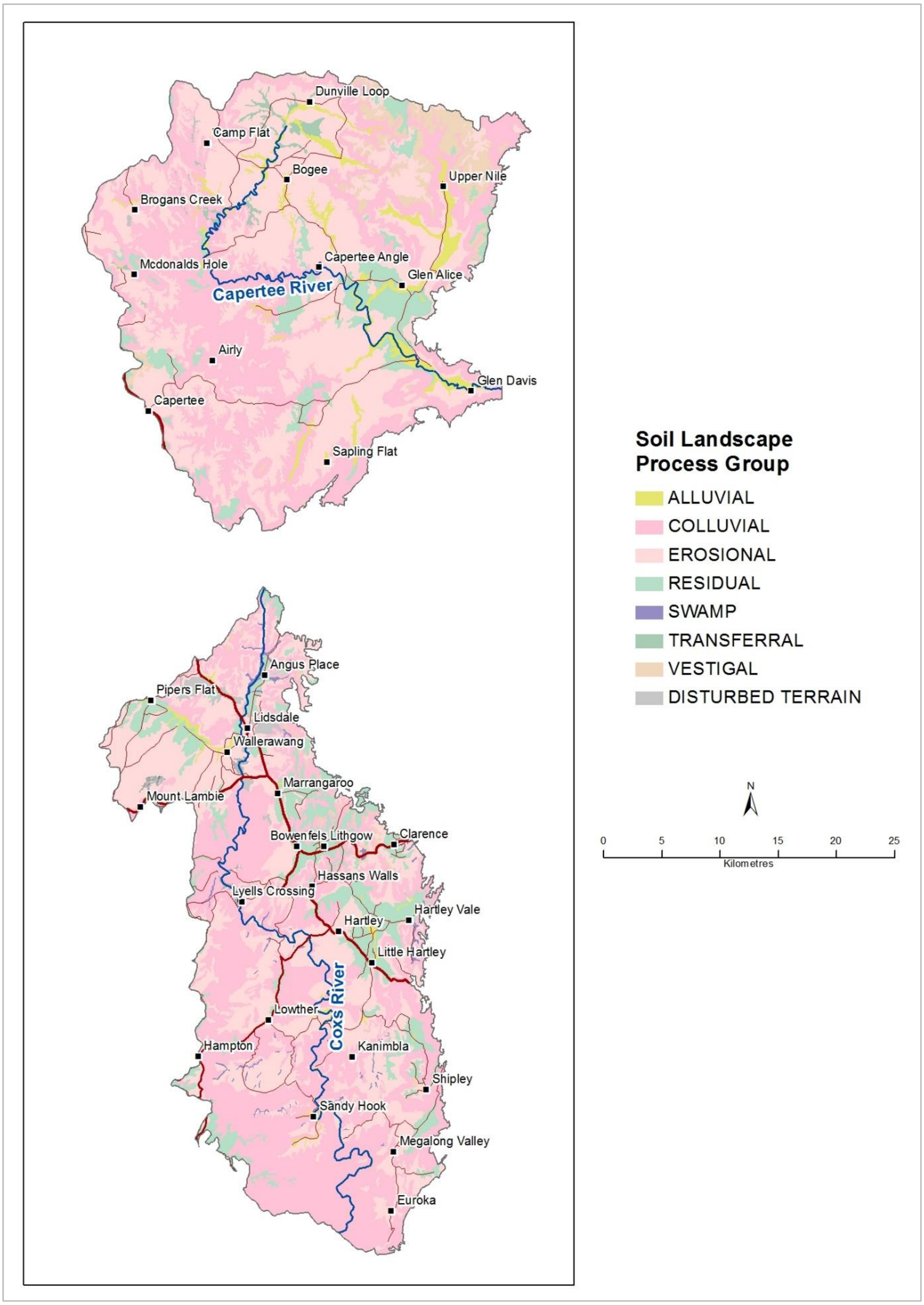

Figure 8 Soil Landscapes of the Capertee Valley and Coxs River Valley (DECC 2008)

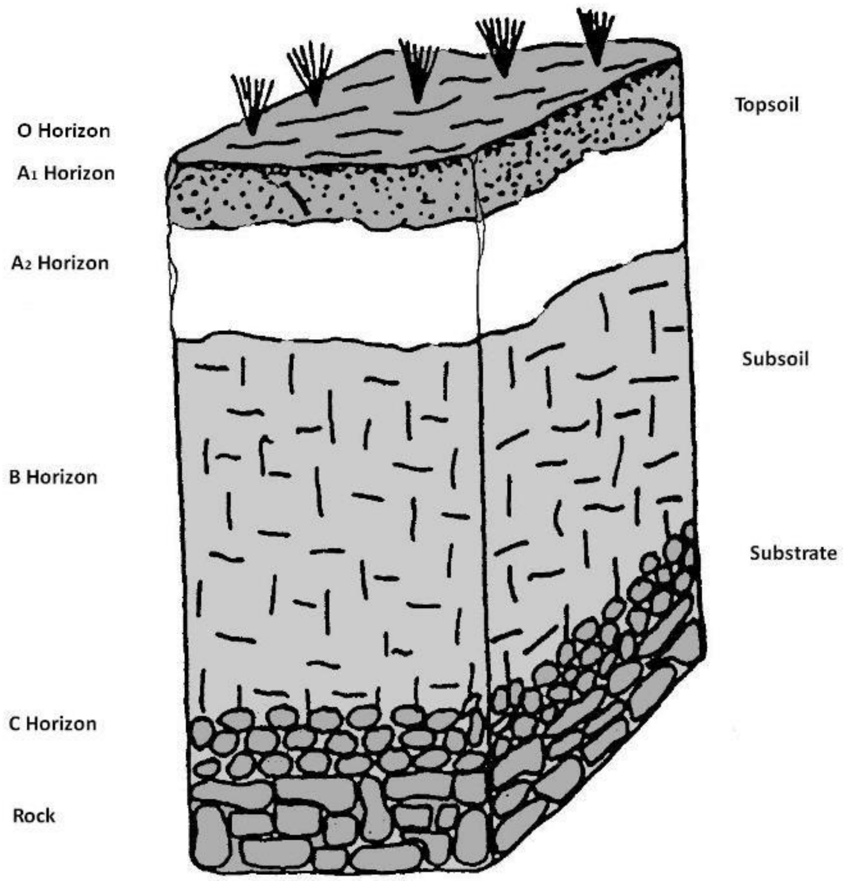

Figure 9 Idealised soil profile showing the various soil layers (modified from Murphy and Murphy 2000)

The organic matter layer (O horizon) varies across the Capertee and Coxs River Valleys. Generally, the higher and wetter an area, the greater the organic matter content. Lower and less elevated mid-slopes are often organic matter deficient. Human activity may have reduced organic matter and structure within the topsoils (A_1 horizon). This has impacted on the water storage capacity of the soil and has removed the protective layer from healthy soils which buffers against mobilisation of salts. Further compounding this problem is the sandy nature of some parent material, which does not have a high water storage capacity and readily transmits water.

The A_1 horizon is generally shallow and fragile on hill slopes and crests. An A_2 horizon is commonly found immediately below the A_1 horizon, characterised by its paler colour relative to the A_1 horizon. In some instances, a bleached A_2 horizon with a white appearance may develop. These layers mostly set hard when dry, blocking root development, and often indicate drainage and salt problems. Bleached A_2 horizons are evident in many of the drainage lines and adjacent lower slopes.

Subsoils (B horizons) are generally light to medium clays. Their structure determines the rapidity with which these layers drain and their boundaries with other layers are important factors in determining the movement of salt in the landscape. Ideally, soils will have a deep loamy topsoil, grading into a friable light clay subsoil with a neutral pH. A subsoil with a blocky or massive structure tends to be not as freely draining or as accessible to roots as a soil which readily crumbles (friable) into soft small peds (common soil aggregates).

2.2.7 Land use

Gundungurra Country extends from the Blue Mountains at Hartley and Lithgow, through the Burragorang and Megalong Valleys. To the east, it extends at least as far as the Nepean River, and in the south at least as far as Goulburn, and possibly to Tumut. Historically, the Gundungurra People have also been referred to as the Mountain People, Nattai, Burragorang or Wollondilly Tribes (Macquarie University Library 2010).

Wiradjuri Country extends from the western foothills of the Blue Mountains and Lithgow, through Bathurst, Orange, and Dubbo to Nyngan in the far west; in the south it stretches to Albury, occupying almost the entire length of the Lachlan and Murrumbidgee Rivers, as well as 100km along the Upper Murray.

Throughout the Lithgow and Blue Mountains areas there are many Aboriginal sites, including rock shelters, burial grounds, carved trees and rock art. The area is thought to have been an important trade route from the east to the Central West.

The first Europeans to see the Hartley Valley were the explorers Blaxland, Lawson and Wentworth, with their four servants, in May 1813. The valley was forested land, covered with trees and good grass. Late in 1814 the first road was made by William Cox, which brought people off the plateau down into the valley.

The first European inhabitants of the Hartley Valley were stockmen working for the Government and private individuals. Recognising the value of the good pasture country for stock, Governor Macquarie quickly established a stock station for cattle near Mount York. Initially, the Hartley Village, which grew around the Hartley Court House (constructed in 1837), became the administrative centre for the area. The Lithgow area, and in particular Rydal, expanded rapidly following the discovery of gold at Bathurst in 1851 (Highway West 2010; Lithgow Tourism 2010). By 1866 a track for a railway was being surveyed over the Blue Mountains and in 1869 the railway to Lithgow via the 'ZigZag' was completed. Because the export of coal and iron was commercially viable, Lithgow became industrialised and the town of Lithgow was established. It became the major industrial centre of NSW in the last quarter of the 19th century and the railhead for the western region.

James Rutherford established the iron industry in 1875 when he erected a blast furnace to manufacture pig iron. By 1900 Lithgow had produced the first steel manufactured in Australia. Copper smelting, breweries, brickworks, pipe and pottery works followed. Meat refrigeration was also established by Thomas Mort in 1875. The first Australian chilled meat from Lithgow arrived in England in 1880.

The decline of Lithgow's industrial heyday made way for light industry after World War II. In the late 1950s, a power generating plant was built at Wallerawang, paving the way to produce energy from local coal.

The Capertee Valley, home to the original inhabitants, the Wiradjuri people, was first traversed by the European explorer James Blackman, who journeyed through to the Mudgee area in 1821. Sheep properties were established in the valley during the 1840s, producing quality wool. Capertee Village became a rest stop for travellers to Mudgee due to the location of a good water source. The village sprang up with a few homes, an inn and a post office, with railway construction completed in 1882. With the coming of the railway, the valley opened up for mining of coal, limestone and oil shale. The Glen Davis Shale Oil Works, in the Capertee Valley, was one of the largest employers in the area. Producing gasoline, the operation was an important strategic resource during the war era.

While agriculture and industry had been the social and economic drivers of settlement and land use, today the diverse native terrestrial biodiversity of the Hawkesbury-Nepean is conserved at significantly different levels across the catchment area. More than half the catchment is bushland protected in national parks, such as the Blue Mountains and Wollemi National Parks, both of which are part of the Greater Blue Mountains World Heritage Area.

The native vegetation communities found on the Triassic sandstone soils in the national parks, state forests and Water NSW ‘special areas’ are well protected. However, granite, basalt and shale soils are more common in the rest of the catchment and the native vegetation communities that grow on these soils have been extensively cleared.

The listing of the Greater Blue Mountains as a World Heritage Area is based on its outstanding biodiversity values, with World Heritage almost entirely within the Hawkesbury-Nepean catchment. The Greater Blue Mountains area represents a major component of global biodiversity. It has provided exceptional biological stability that has allowed some environments and their biota to remain largely unchanged over geological time. A species of global significance, a living fossil of the plant world, the Wollemi pine (*Wollemia nobilis*), is preserved in this World Heritage Area.

Drinking water for metropolitan Sydney is another of the catchment's important uses, as the Coxs River flows into Lake Burragorang and, with the Upper Nepean storages, they together supply 97% of Sydney's drinking water. The 45% of the Hawkesbury-Nepean catchment that is bushland in national parks and inner catchment areas (or Special Areas), directly supports this major use by ensuring a high level of protection for water originating from these lands. The headwaters of the Coxs River supply three reservoirs: Thompson Creek Dam, Lake Lyell and Lake Wallace – which are part of the Wallerawang and Mount Piper power station scheme and supply 23% of the State's power.

The catchments are used for activities including grazing, horticulture and hobby farms, tourism and recreation, increasing rural residential subdivision, development of major corridors (transport and infrastructure), mining and other extractive industries.

Land use pressures in the Capertee and Coxs River Valleys can be attributed to two significant uses:

Agricultural and Public Land Use: Land uses in the rural areas of the Capertee Valley include grazing, rural residential/hobby farming and conservation areas, such as for habitat plantings for threatened species. Significant farmlands in the far north-west of the catchment have been prone to significant environmental issues, such as soil erosion. Historically, some diamond mining has occurred in the area (Mount Airly). The upper escarpment landscape remains under remnant vegetation, mainly as national parks, including Wollemi National Park and Gardens of Stone National Park.

The land use in the Coxs River catchment is similar. However, because of landscape attributes and proximity to larger centres the land use is more intensive. Grazing of beef cattle, sheep and horses on freehold land is the most widespread land use. Smaller areas are devoted to horticulture, state forests, coal mining, power stations, and residential urban use (Lithgow, Marrangaroo, Wallerawang, Cullen Bullen). Coal mines and some quarries are scattered throughout.

The landform features known as ‘pagodas’ are largely contained within the Blue Mountains National Park on the upper escarpment, but smaller areas are found within the Newnes State Forest. Native forest exists on steeper areas, where the landscape remains largely undeveloped.

Urban and Peri-urban Land Use: Land use in the urban and peri-urban parts of the Hawkesbury-Nepean catchment present different issues from those in the rural and native vegetation or reserved areas that make up the balance of the landscape. The density of human population, the change in the soil surface layer, an increase in instream storage of water (farm dams) and the interception of rainfall (tanks) has changed the amount and nature of water flow. Many small blocks are managed by different owners, which increases the variety of management methods, compared with traditional large farms where practices are often consistent across broad areas.

Property size may also affect appropriateness and usefulness of different management techniques: a change of management that might be considered for a small part of a large property could be unrealistic for a small recreational or hobby block.

Salinity signals in urban areas may manifest in infrastructure such as buildings and roads, which have replaced the plant cover. Landforms in the Coxs River catchment express subtle indicators of dryland salinity. Salinity may have resulted in noticeable crop yield decreases (e.g. Capertee Valley); these indicators may not be evident where the property is being used for miscellaneous recreation.

2.2.8 Vegetation

Changes in vegetation communities reflect the transition in elevation and rainfall across the region. The communities can be ascribed to seven Australian biogeographic regions (Figure 10):

- Bathurst
- Burragorang
- Capertee Uplands
- Capertee Valley
- Hill End
- Oberon
- Wollemi.

These bio-regions are large, geographically distinct areas based on common climate, geology, landform, native vegetation and species. They have been generated under the Interim Biogeographic Regionalisation for Australia (IBRA) (Department of the Environment 2012). IBRA is updated as improved spatial mapping and information on vegetation communities and ecosystems becomes available from state and territory agencies.

The distribution of native vegetation around the Capertee and Coxs River Valleys is closely related to the underlying geology, landscape morphology and climatic conditions. Steep slopes, ridges and plateau areas typically remain heavily wooded under remnant forest, while vegetation formations on more fertile country with greater productivity potential are more likely to have been cleared. Other clearing has also taken place along with urban and industrial development.

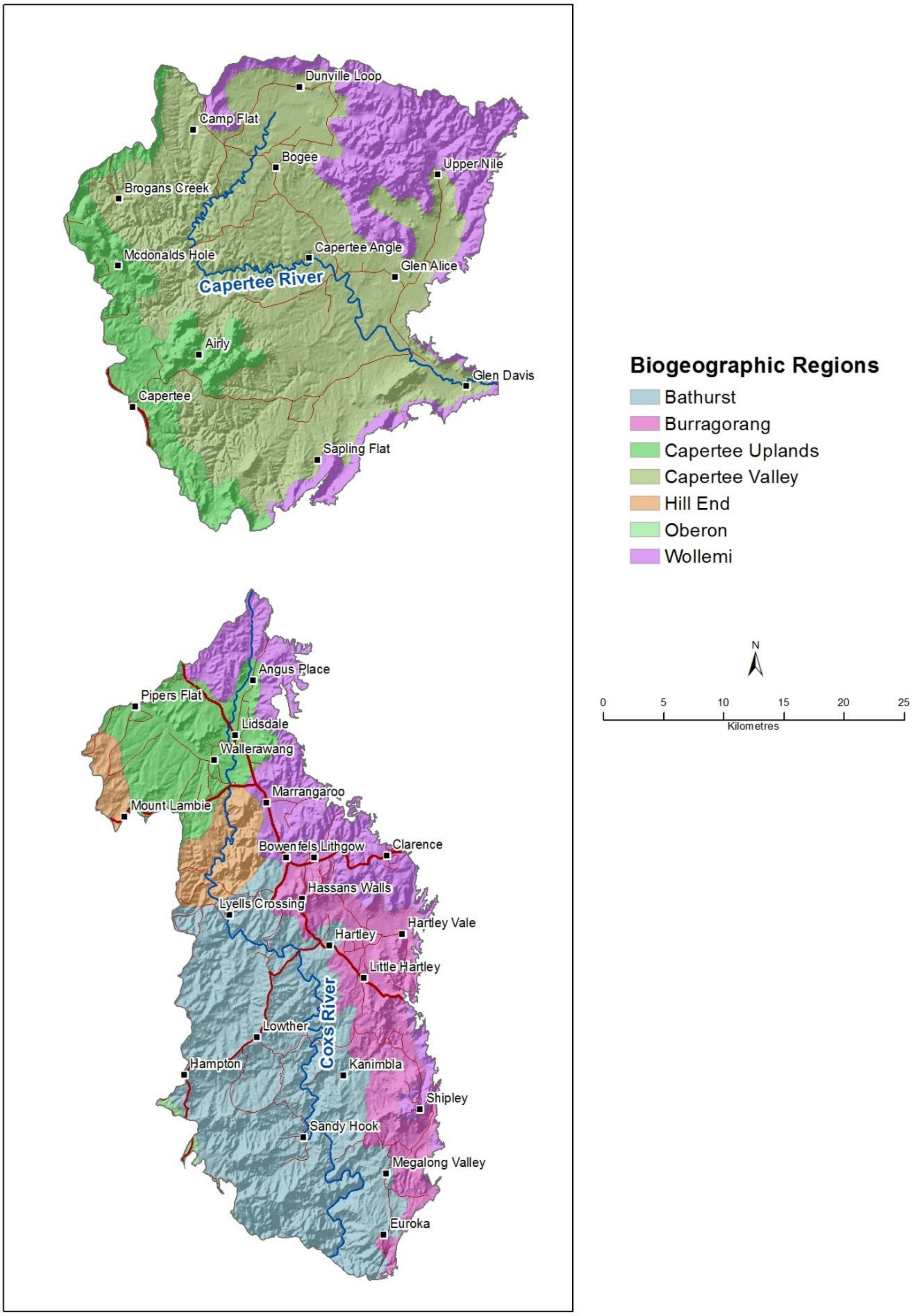

Figure 10 IBRA Regions covering the Capertee (top) and Coxs River (bottom) Valleys (Department of the Environment 2012)

Broad trends in remnant community distribution follow topographical features. A typical transect of vegetation formations from plateau to footslopes and valley floor is shown below in Figure 11.

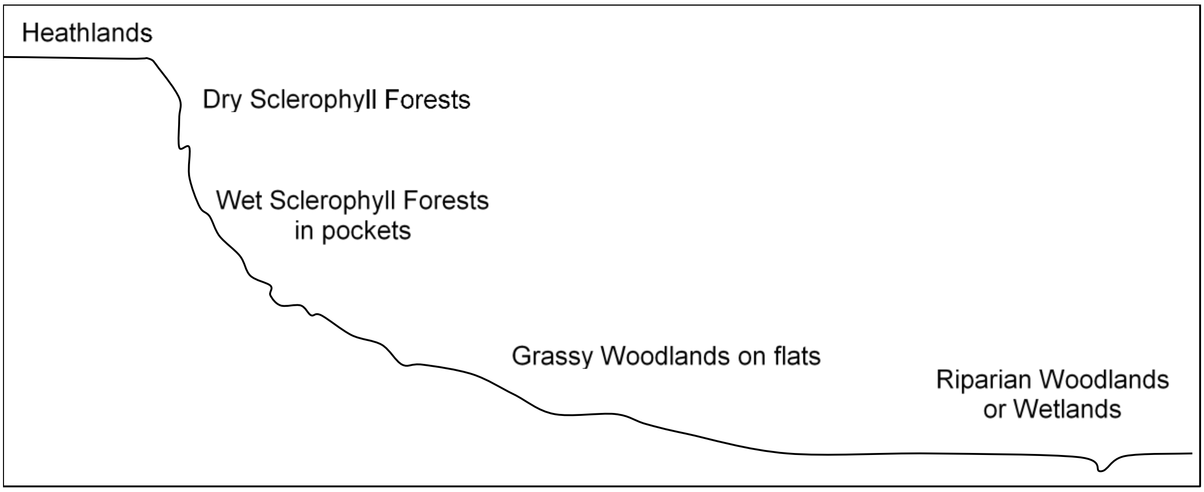

Figure 11 Typical transect of vegetation formations in the Capertee and Coxs River Valleys

Vegetation communities on the plateau and pagoda landscapes of Narrabeen Sandstone tend to be heathlands or dry sclerophyll forests, suited to sandy and skeletal soils. Species include *Leptospermum* spp., *Calytrix tetragona, Hakea* spp., and on deeper soils *Eucalyptus punctata, E. piperita, E. cannonii* and *E. sieberi*. A common tree species in some pagoda landscapes is *E. rossii*.

There is a distinct vegetation change from the sandstone ridges to the upper slopes, where the higher altitude shrubby forests and woodlands merge into wet sclerophyll forests. The narrow band of wet sclerophyll forest that features most prominently in the Capertee Valley tends to correspond to protected areas below sandstone cliffs, where aspect suits a mesic vegetation community. Species in such areas include *Angophora floribunda, Eucalyptus blaxlandii, E. cypellocarpa, E. polyanthemos, E. punctata* and understorey species such as *Persoonia linearis, Solanum prinophyllum* and wattles.

Vegetation communities that persist on the footslopes and valley plains grade from dry sclerophyll forest to grassy woodlands as the topography flattens out onto the valley floor. Rises on the valley floor are dominated by grassy woodlands. Remnant canopy trees may include *Eucalyptus albens, E. moluccana, E. punctata, E. melliodora, E. blakelyi, E. polyanthemos* and *Brachychiton populneus*, with a *Bursaira spinosa* understorey. Typically, this is where the endangered Box-Gum Woodlands are found.

Some vegetation communities are restricted to particular geological substrates. For example, in patches of the Capertee Valley where limestone persists, specific communities of grassy woodland have adapted to limestone substrates. These communities typically include low trees and shrubs of acacias and *Xanthorrhoea johnsonii* under a *Eucalyptus moluccana* and *E. albens* canopy, or a very low and scattered understorey of *Brachychiton populneus, Pimelea latifolia* subsp*. elliptifolia, Solanum brownii* and *S. prinophyllum*.

In the Coxs River Valley, landscapes heavily influenced by basalt substrates support plant communities, such as the endangered Tableland Basalt Forest in the north-east of the catchment.

Threatened species and weeds

A number of the local plant communities are unique and endemic to the Capertee Valley area. Two communities are listed as endangered ecological communities (EECs) under the New South Wales Threatened Species Conservation Act (1995). These are the Genowlan Point Allocasuarina nana heathland, exclusively on the Genowlan Mountain in the south-west of the Capertee Valley, and the White Box-Yellow Box-Blakely's Red Gum Woodland, widely distributed throughout the valley floor.

The Coxs River Valley supports the endangered ecological community of Tableland Basalt Forest.

Individual threatened species listed on the NSW threatened species register are also found in the Capertee and Coxs River Valleys. These include four endangered species: *Grevillea obtusiflora* subsp. *fecunda* (NSW NPWS 2001, Makinson 1997); *Phebalium bifidum* (NSW SC 2005); *Asterolasia buxifolia* (NSW SC 2002); and Genowlan Pea (*Pultenaea* sp. Genowlan Point), which is known from a single population at Genowlan Point in the Capertee Valley and is also listed as critically endangered on the national threatened species register (NSW SC 1998). A total of 9 vulnerable plant species occur in the Capertee Sub-regions Parts A and B, and 7 in the Bathurst Sub-region in the Coxs River Valley.

There are a number of plant species classed as noxious weeds in the Hawkesbury-Nepean Catchment Management area (HNCMA & NSW DPI 2007), including *Salix* spp. (willows) and *Rubus fruticosus* (blackberry), also listed as Weeds of National Significance and found within the study areas. These species lists are continually being updated and reviewed.

Vegetation and HGLs

Native vegetation is highly influenced by geology and landscape morphology and can represent underlying landscape variability. Vegetation may indicate specific landscapes and landscape elements: vegetation "signatures" of a suite of communities, or of a single vegetation community, can be indicative of particular geophysical or geological characteristics. Vegetation is therefore a very useful key to recognising differences between and within landscapes, such as HGLs.

The coupled distribution of a particular species with a landscape element is also possible. Evident coupling occurs with *Callitris* spp., which often occur at greater densities on sodic slopes (or slopes that have been protected from fire) and kurrajong (*Brachychiton populneus*), often present on fertile plains. These are general observable patterns, not strictly diagnostic of landscape features if looked for in isolation; however, they correspond closely with differences within a landscape unit. For example, *Callitris* occurs densely on the sodic bench of Illawarra Group Sediments in the Mount Marsden and Horse Gap HGLs, whereas it is less common elsewhere in those HGLs.

Multiple vegetation communities, as defined by NSW vegetation surveys (DEC 2006, Tozer *et al*. 2010), are found with restricted distributions in the Capertee and Coxs River Valleys. Some of these distributions coincide with boundaries defined for HGLs. Correlations between extant vegetation communities and HGL extent therefore reinforce landscape differences that are defined primarily on hydrogeological features. Examples of such correlations are Angus Place HGL, encompassing the entire distribution of Coxs Permian Red Stringybark-Brittle Gum Woodland in the Coxs River Valley (it is not found elsewhere in the study area), and the Tableland Grassy Box-Gum Woodland, which is entirely within Hartley HGL.

Vegetation assemblages are described in the HGL templates within a classification hierarchy and grouped according to the most frequent (major or "signature") Local Classes present and less frequent (minor) Local Classes. Local Class communities within the major vegetation assemblages may be used as a guide to HGL distribution.

Classification of vegetation assemblages

The native vegetation in NSW has previously been classified under the NSW Native Vegetation Mapping Program (NVMP) at a variety of scales. The NVMP aimed to produce a consistent coverage of vegetation maps throughout the state, incorporating data from a range of vegetation surveys; revising and merging them into a uniform data set for NSW. This mapping is being continually updated. Future updates will be incorporated in to the State Vegetation Type Map (SVTM) - https://www.environment.nsw.gov.au/vegetation/state-vegetation-type-map.htm.

The hierarchy of vegetation classification is:

- Formation
- State Class
- Local Class.

Formation

The Vegetation Formations of NSW, according to Keith (2004), are broad categories developed to describe the structure of entire vegetation communities. They are distinguished by structural and physiognomic features and their descriptions include groundcover, mid-storey and overstorey species type, distribution and structure. A range of Formations occur within the Capertee and Coxs River Valleys and, for the purposes of HGL templates, they are simply listed in the hierarchy without detail (a detailed list with descriptions of these broad Vegetation Formations was included in the Phase 1 Report: Vine et al. 2008). As multiple State Classes fit within each Formation, the Formation is listed in plural form.

State Class

Within each Vegetation Formation are a series of vegetation classes, referred to in this report as State Classes. These State Classes are mainly defined by overall floristic similarities (i.e. shared species) and further refine the structure and variety of species within the vegetation grouping. As multiple Local Classes fit within the State Class, the State Class is listed in plural form. As multiple State Classes fit within a single Formation, Classes are grouped together according to Formation.

Local Class

The most detailed and homogenous units of plant groupings in the hierarchy are known as plant communities, which are assemblages of plants species that live together, generally at the same time. They are referred to in the HGL templates as Local Classes. As multiple Local Classes fit within a single State Class, Local Classes are grouped together according to State Class, and consequently within a Formation.

Broad Vegetation Classes are shown in Figure 12. For more information, detailed descriptions of all the vegetation types and classes can be found in the corresponding reports of *The natural vegetation of the Wallerawang* 1:100 000 Map Sheet (Benson and Keith 1990), *Wollemi National Park vegetation survey* (Bell 1998), *Native vegetation map report series. No. 4* (Tindall *et al*. 2004), *Vegetation of the Western Blue Mountains* (DEC 2006), and *Native Vegetation of southeastern NSW* (Tozer *et al.* 2010).

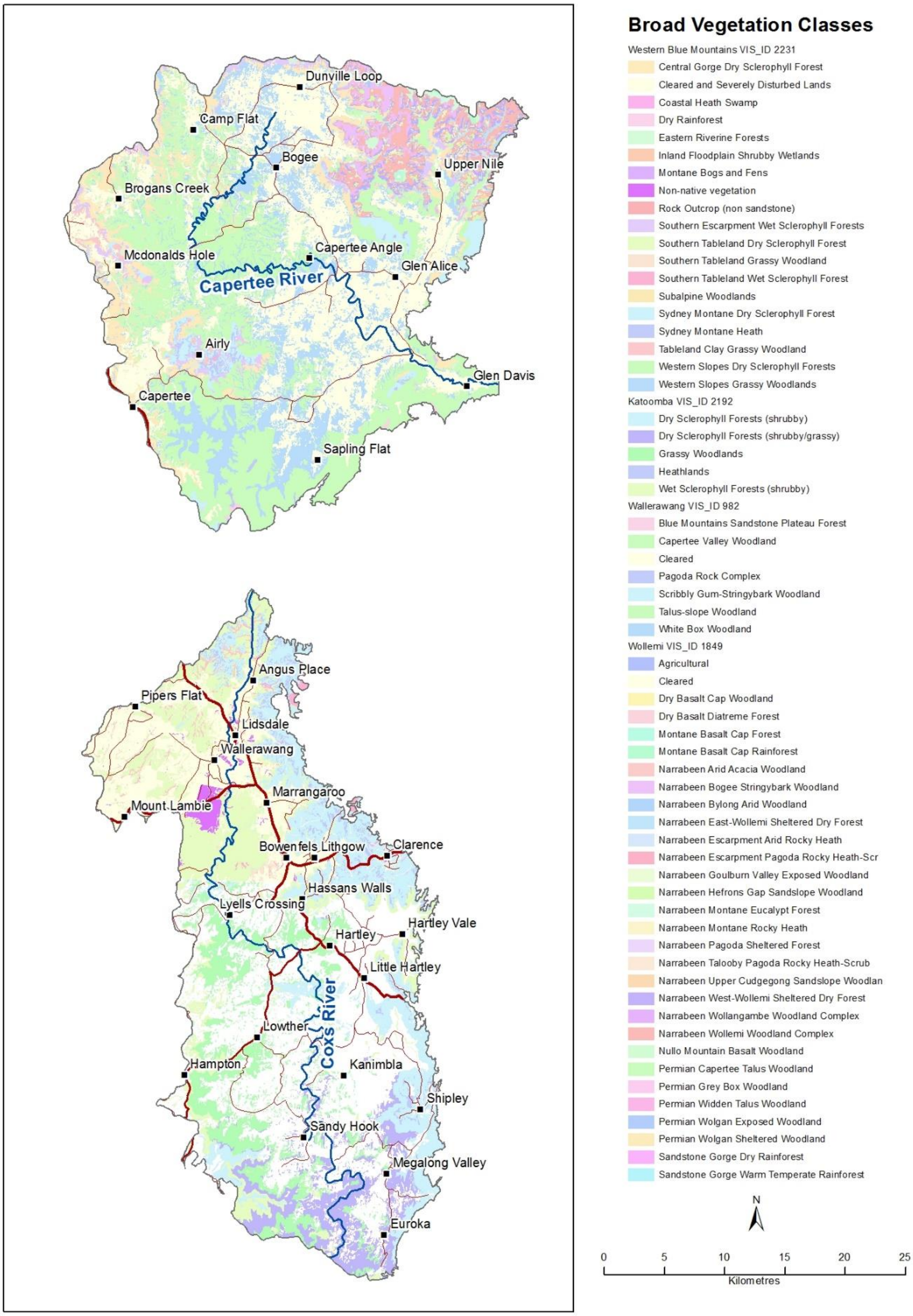

Figure 12 Distribution of broad NSW native vegetation classes in the Capertee Valley and Coxs River Valley
(DIPNR 2010a-e)

3. Hydrogeological Landscapes (HGL)

A HGL characterises a discrete unit of land within which salinity manifests in a consistent way and can be managed with a specific combination of land use practices. However, the combination of salinity response and salinity management options will usually differ between HGLs.

For ease of comparison and consistency, descriptions of HGLs use the following standard structure:

- how salinity manifests itself in the landscape – salinity is described in terms of its dryland occurrence, salt export from the HGL and the impact on water quality
- the amount of salt stored in the landscape and how available it is for export (i.e. mobility)
- the relative hazard, as defined by the impact of salinity, and its likelihood of occurrence
- lithology, dominant geology, landforms
- soil landscapes, land and soil capability, land use, land degradation
- vegetation
- hydrogeology, by quantifying a range of groundwater and catchment characteristics including aquifer type, catchment size and residence time;
- function of the HGL in terms of catchment salinity context (landscape function)
- management strategies to improve or maintain function
- specific management actions to implement appropriate strategies.

In addition, each HGL unit description includes:

- conceptual cross-sections
- management diagrams
- landscape photos
- references.

In the Capertee and Coxs River study areas, HGL polygon determination was primarily based on geomorphic, stratigraphic and geologic interactions, informed by geology and soil boundaries, terrain, vegetation distribution and climate information. This is illustrated in the third volume reporting on the Capertee Valley and Coxs River Valley HGL Project, which covers the mapping component of the study.

Initial field work was undertaken to verify the applicability of the various datasets to salinity processes and to define the HGLs. Primary datasets used were:

- geological mapping – 1:250 000 coverage
- soil landscape mapping
- hydrological information
- groundwater information
- stream EC measurements
- field reconnaissance
- saline site mapping of the Capertee Valley and Lithgow areas, remapped by DECCW during 2008 and 2009.

The Singleton, Sydney and Bathurst 1:250 000 geology maps (respectively, Rasmus et al.1969, Bryan 1966, Packham 1968) were used to separate the area into major lithological groups with similar hydrological properties, regolith depth and weathering characteristics. For example, Devonian metasediments and igneous bedrock differ from the surrounding Permo-Triassic sedimentary dominated landscapes. Field reconnaissance confirmed the depths and extent of different bedrock and the intersection of specific stratigraphic beds with the modern land surface.

The soil landscapes information from the Wallerawang 1:100 000 soil landscape map and Hawkesbury-Nepean Catchment soil and land resources map (King 1993 and DECC 2008, respectively) were used to better understand the terrain and differences in regolith. Field reconnaissance confirmed the depths of bedrock and the nature of soil materials and recent salt site mapping detailed local salinity manifestations.

The distribution, variability and extent of vegetation assemblages were noted as a component of this work and used in characterising the HGL units (DEC 2006, Tozer et al. 2010, Keith 2004). Distribution of some vegetation communities was used to clarify boundaries between landscapes.

Maps showing the distribution of the 24 Hydrogeological Landscapes for the Capertee and Coxs River Valleys, their overall salinity hazard, management area distribution and a summary table of HGL attributes, are contained in Appendix A.

The detailed unit descriptions for the 24 HGLs derived for the Capertee and Coxs River Valleys are contained in Appendix B.

3.1 Salinity risk and priority determination

Risk analysis in the HGL framework is specifically designed to determine the landscape impacts and hazards of salinity in a particular HGL area. At the start of each HGL unit description template, the factors determining salinity risk – land salinity, in-stream salt load, and in-stream EC – are each rated high, moderate or low and diagrammatically represented using a circular colour coded chart (Figure 13).

Example Hydrogeological Landscape

LOCALITIES	**Jonestown, Smithsville**
MAP SHEET	**Bathurst 1:250 000** **Sydney 1:250 000** **Singleton 1:250 000**
CONFIDENCE LEVEL	**Low**

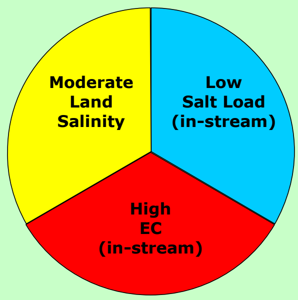

Figure 13 Example HGL unit description, with circular chart illustrating the impacts of land salinity, in-stream salt load and EC

Impact ratings for the Capertee and Coxs River Valleys HGL project were assigned based on the conditions listed in Table 3. Salt load is a function of the stream salinity (EC) and volume of water flowing in the stream.

Table 3 Conditions used to assign impact rating to Capertee and Coxs River Valleys in HGL circular charts

Impact	Land Salinity	Salt Load	EC (stream salinity)
Low	No land salinity observed or mapped	Any flow; <250 µS/cm	Any flow; <250 µS/cm
Moderate	Conditions exist that support development of land salinity (e.g. waterlogging). Areas affected are small and generally seasonal.	Intermittent flow;>800 µS/cm (observed), or perennial flow between 250 and 800 µS/cm.	Intermittent flow; >800 µS/cm (observed), or perennial flow between 250 and 800 µS/cm.
High	Permanent scalds commonly observed.	Perennial flow; >800 µS/cm or spikes >1500 µS/cm.	Perennial flow; >800 µS/cm, or observed readings >2500 µS/cm.

3.1.1 Mobility and overall salinity hazard

Salt mobility is also used to distinguish salinity behaviour. Salt in a landscape can be available to varying degrees in different salt stores. The basic 'rule of thumb' is that sand constitutes a low salt store with a high availability, and clay has low availability but high salt store. The relationship between salt availability and salt store is tabulated in each HGL unit description, as illustrated in Table 4.

Table 4 Relationship between salt availability and salt store used to describe the mobility of salt in a landscape. The mobility is described using three classes ranging from low to high

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store	**Moderate**	**High**	**High**
Moderate salt store	**Low**	**Moderate**	**High**
Low salt store	**Low**	**Low**	**Moderate**

The overall salinity hazard and resultant priority for action can be inferred from the interaction of land/load/EC factors. Salinity assessment of a landscape is made by determining salinity hazard using a standard risk format. The matrix of 'potential impact' and 'likelihood of occurrence' determines the overall salinity hazard for each HGL.

This hazard integrates the salinity impacts in a landscape. The overall hazard is influenced by regolith thickness, salt storage, landscape shape and underlying geology. The relationship between potential impact, likelihood of occurrence and overall salinity impact is tabulated in each HGL description, as illustrated in Table 5. A map of the overall salinity for Capertee and Coxs River Valley HGLs is provided in Appendix A2

Table 5 Relationship between potential impact of salinity and the likelihood of salinity occurring, as used to assign overall salinity hazard. The overall hazard uses five classes ranging from very low to very high

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence	**Moderate**	**High**	**Very High**
Moderate likelihood of occurrence	**Low**	**Moderate**	**High**
Low likelihood of occurrence	**Very Low**	**Low**	**Moderate**

3.2 Hydrogeological Landscape (HGL) features

Each HGL characterises a discrete unit of land within which salinity manifests in a similar way and can be managed with a specific combination of land use practices. The salinity response and salinity management options will usually differ between HGLs. For consistency and ease of comparison, the unit description for each HGL follows a similar format and describes a number of features that are typical of that HGL.

3.2.1 Rainfall

The Capertee and Coxs River Valleys cover a range of rainfall zones. HGL unit descriptions give a range of mean annual rainfall figures. These are based on the annual precipitation bioclimatic parameter from BIOCLIM climatic modelling (DECCW 2009).

3.2.2 Lithology

Lithology refers to the nature of rocks at the macroscopic level, in terms of their colour, texture, and composition. In fractured rock landscapes, such as those in the Capertee and Coxs River Valleys, the lithology of the underlying rocks is important as it influences many other landscape features, such as regolith, landform and soils. Lithological characteristics are one of the key datasets for determining HGL boundaries.

Lithological descriptions for the Capertee and Coxs River Valley HGL project come from Rasmus et al. (1969), Raymond et al. (1998) and Geoscience Australia (2016).

3.2.3 Regolith and landforms

Regolith is typically defined as all the material between fresh bedrock and the land surface (Scott and Pain 2008). It includes all soil horizons, alluvial, colluvial and aeolian material, as well as weathered bedrock and any indurated or hardened layers in the landscape.

The nature and distribution of regolith materials is strongly influenced by the following (Scott and Pain 2008; Taylor and Eggleton 2001):

- **Parent material –** the chemistry of the parent material influences the chemistry of the regolith materials. The weathering pathways and products derived from parent material can be predicted if the mineralogical make-up of the parent material is known.

- **Climate** – temperature and rainfall both have a major impact on regolith development. However, rainfall is particularly important in forming regolith materials. Water is the primary agent in the weathering process, therefore, as rainfall increases, so too do weathering rates. Generally, areas with higher temperatures experience higher weathering rates than those with the same rainfall and lower temperatures.
- **Topography** – this influences erosion across the landscape. Areas with a lower gradient commonly have lower erosion rates than those with a higher gradient.
- **Biota** – biological activity in the regolith can consist of anything from termite to marsupial activity. This type of activity can influence the structure of regolith materials and the rate at which they develop. A higher occurrence of biological activity may result in an increased rate of regolith development.
- **Time** – materials that have been subjected to weathering processes for longer periods are typically more weathered than those subjected to weathering for a shorter period.

Landforms descriptions are based on their morphology (size and shape). The terminology used generally relates to the Australian Soil and Land Survey Field Handbook compiled by the National Committee on Soil and Terrain (NCST 2009).

3.2.4 Soil landscapes

Soil landscapes provide knowledge about the distribution and attributes of soil and land resources. The relevant soil landscape map and accompanying report are invaluable resources for building robust HGL models. On the relevant 1:100 000 soil landscape map sheets some soil landscapes broadly correlate with HGL boundaries, but for other HGLs the soil landscapes are either wholly or partially merged while others are subdivided.

Soil landscapes are areas of land that “have recognisable and specifiable topographies and soils, that are capable of presentation on maps, and can be described by concise statements” (Northcote 1979). The soil landscape concept integrates both soil and topographical constraints into one unit for the purpose of land management (Hazelton 1992).

They are comparable to land systems (Christian and Stewart 1953, Walker 1991) in that landform and geology are important factors to determine unit boundaries, but soil landscapes usually place greater emphasis on the soils and less on the vegetation. Soil landscapes differ from soil associations (where recurring soil patterns are mapped), in that greater significance is given to geomorphic processes. The main difference from HGL mapping is that for soil landscapes more emphasis is placed on the top 2 m of the regolith profile and less on water movement.

In soil landscape mapping soils are described in terms of soil layers, in addition to the more traditional soil profile description. These layers are termed soil materials and are defined by Atkinson et al. (1985) as *“... three-dimensional soil entities which have a degree of homogeneity and lateral continuity”*. Each soil material is defined and described in terms of its readily recognised and characteristic morphological properties. The definitive attributes may vary from one soil material to another, depending on what is recognisably characteristic of the material. In most cases each soil material has a consistent set of properties and limitations.

Soils can be classified using traditional soil taxonomic systems, such as Great Soil Groups (Stace et al. 1968), Principal Profile Forms (Northcote 1979) or the Classification System for Australian Soils – ASC (Isbell 2002). ASC is used throughout this report as it is available for the entire study area. Great Soil Groups are also generally provided.

Soils were examined and described in detail at key sites and inspected at many other sites. At each described site, soil morphological data and site information were recorded on Soil Data Cards (Milford et al. 2001). Landscape boundaries and descriptions were also checked during site inspections. Soils exposed in road batters, building sites, trenches, backhoe pits and hand-augered holes were described. Sufficient field sampling within each soil landscape identified and described the range of soil materials present and enabled individual descriptions of their occurrence and relationships. At least one sample was collected from each soil material for laboratory analyses.

3.2.5 Rural land capability

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degrading soil, land, air and water resources. Failure to manage land in accordance with its capability risks degrading resources both on- and off-site, leading to decline in natural ecosystem values, agricultural productivity and infrastructure functionality.

A land capability classification has been developed to describe the agricultural enterprises that can be sustained on different land types. The classes are based on the potential for sustainable use if the land is developed, not on current land use. Table 6 summarises rural land capability classes, conservation practices and implications (Emery 1986).

The capability class into which any type of land is placed depends on the physical characteristics of the site, the soils and specific limitations on their use, land management constraints and the local climate. The protection land requires depends upon the proposed use and topographic features, such as slope length and gradient, the erodibility of the soil, the frequency of high intensity rain storms or strong winds, and the types of land degradation likely to occur at the site.

3.2.6 Land use

Land is used for agriculture, forestry and nature conservation in the Capertee and Coxs River Valleys. The list of land uses given in the HGL unit descriptions is based on those given in soil landscape descriptions in each HGL and on observations made in the field.

3.2.7 Key land degradation issues

The list of land degradation issues given in the HGL unit descriptions is based on those in soil landscape descriptions relevant to each HGL. These issues have been observed and are currently occurring.

3.2.8 Native vegetation

Native vegetation is influenced by geology and landscape characteristics. It can indicate the variability of underlying landscape conditions. Changes in native vegetation often indicate differences within and between HGLs.

Native vegetation characteristics are described in the HGL unit descriptions. These descriptions are derived from Keith (2004) and DEC (2006).

Table 6 Rural Land Capability classes – general definitions (Emery1986)

Land classification and soil conservation practices				Interpretations and implications
Suitable for regular cultivation		I	No special soil conservation works or practices.	Land suitable for a wide variety of uses. Where soils are fertile, this is land with the highest potential for agriculture, and may be cultivated for vegetable and fruit production, cereal and other grain crops, energy crops, fodder and forage crops, and sugar cane in specific areas. Includes "prime agricultural land".
Suitable for regular cultivation		II	Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotation.	Usually gently sloping land suitable for a wide variety of agricultural uses. Has a high potential for production of crops on fertile soils similar to Class I but increasing limitations to production due to site conditions. Includes "prime agricultural land".
Suitable for regular cultivation		III	Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotation.	Sloping land suitable for cropping on a rotational basis. Generally used to produce the same type of crops listed for Class I, although productivity will vary depending upon soil fertility. Individual yields may be the same as for Classes I and II but increasing restrictions due to the erosion hazard will reduce the total yield over time. Soil erosion problems are often severe. Generally fair to good agricultural land.
Suitable for grazing	Occasional cultivation	IV	Soil conservation practices such as pasture improvement, stock control, application of fertiliser and minimal cultivation to establish or re-establish permanent pasture.	Land not suitable for cultivation on a regular basis owing to limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Comprises the better classes of grazing land of the State and can be cultivated for an occasional crop, particularly a fodder crop, or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
Suitable for grazing	Occasional cultivation	V	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.	Land not suitable for cultivation on a regular basis owing to considerable limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Soil erosion problems are often severe. Production is generally lower than for grazing lands in Class IV. Can be cultivated for an occasional crop, particularly a fodder crop for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
Suitable for grazing	No cultivation	VI	Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. May include some isolated structural works.	Productivity will vary due to the soil depth and the soil fertility. Comprises the less productive grazing lands. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.

Land classification and soil conservation practices			Interpretations and implications	
Other	**VII**	Land best protected by green timber.	Generally, comprises areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limited grazing and minimising damage by fire. Destruction of trees is not generally recommended, but partial clearing for grazing purposes under strict management controls can be practiced on small areas of low erosion hazard. Where clearing of these lands has occurred in the past, unstable soil and terrain sites should be returned to timber cover.	
	VIII	Cliffs, lakes or swamps and other lands unsuitable for agricultural and pastoral production.	Land unusable for agricultural or pastoral uses. Recommended uses are those compatible with the preservation of the natural vegetation, namely water supply catchments, wildlife refuges, national and state parks, and scenic areas.	
			Class subscripts	Special uses
	U	Urban areas	c	Terrain developed for a specific crop (capability class range IV to VII) as a result of the combination of particular soil, terrain, climatic and economic conditions. The class includes such crops as grapes, bananas, avocados and pineapples.
	M	Mining and quarrying areas	d	Terrain developed for intensive agricultural production and associated with flood irrigation. Class includes land developed for cotton and rice production.

3.2.9 Vegetation assemblages

Details of community structure and distribution within HGLs are provided. The descriptions include species lists from Local Class communities or plants observed in the area. The detail is taken from the finest scale mapping available, 1:25 000 scale for the Capertee Valley (DEC 2006), and 1:25 000 and 1:100 000 scales for the Coxs River Valley (DEC 2006 and Tozer et al. 2010, respectively), or from soil landscape reports.

3.2.10 Hydrogeology

Hydrogeology is the study of the relationships between geological materials, geological processes and water. Surficial geology, soil, physiography and topography all influence the relationship between precipitation and water draining from the landscape (Fetter 1994).

Following rain or snow, water flows overland and enters streams as runoff, or infiltrates into underlying soil and rocks. This infiltration provides soil moisture for plant growth, replenishes groundwater systems and provides interflow and base flow into streams (Freeze and Cherry 1979).

Geological complexity and a paucity of hydrogeological investigations in the Capertee and Coxs River Valleys make it difficult to provide definitive values for hydrogeological parameters. However, it is possible to give typical values based on studies in similar rock types around the world (van Dijk et al. 2004, Domenico and Schwartz 1998, Driscoll 1989, Fetter 1994, Freeze and Cherry 1979).

When describing HGLs, a number of hydrogeological parameters are important:

- **Aquifer type –** describes whether groundwater within an aquifer is confined by an overlying less permeable layer, or unconfined if there are no confining layers. Consideration is also given to the nature of the aquifer material. Unconsolidated aquifers are loose, and groundwater is able to flow through connected pore spaces and voids in the aquifer material. Fractured rock aquifers are made up of consolidated rock and groundwater flow is mainly through fractures in the rock. In porous rocks, additional flow may also occur through pore spaces (dual porosity).
- **Hydraulic conductivity –** describes the capacity of a permeable material to transmit water. It depends on porosity, the degree of connection between pores, grain size and grain sorting.
- **Transmissivity –** describes the capability of an aquifer to transmit water across its saturated thickness. This parameter is generally used for groundwater modelling.
- **Specific yield –** a measure of the capacity of a saturated material to drain by gravity. Due to molecular attraction and capillarity, only a percentage of the total volume of water stored in pores will be released. Generally speaking, the greater the grain size of the material making up the aquifer, the greater the percentage of water released. This parameter only applies to unconfined aquifers.
- **Hydraulic gradient** – describes the change in hydraulic head over distance along a flow-path.
- **Groundwater salinity** – describes the EC of groundwater. This parameter uses saline water classes defined by the AWRC (1976).
- **Depth to water table** – a measure of the depth from the land surface to the water saturated zone in the underlying soil and rock.
- **Typical catchment size –** a general indication of the areal extent across which catchment groundwater processes occur.
- **Scale –** indicates whether local, intermediate or regional scale groundwater flow is predominant (NLWRA 2001). This parameter also considers typical flow length of streams within the HGL.
- **Recharge estimate** – an estimate of the rate of recharge occurring across the HGL.
- **Residence time –** describes the time it takes for a molecule of water to travel through the groundwater system from entry until exit. Longer residence times mean the groundwater has more time to chemically react with the surrounding soil and rock.
- **Responsiveness to change –** indicates the time it takes before land use change (and the associated change to the water balance) can be seen to impact on salinity expressions in the landscape:

3.2.11 Management options

To guide the design of targeted management plans and actions, a Management Options overview is provided for each HGL. This is a summary of the Landscape Function, Management Strategy Objectives, Specific Land Management Opportunities and Constraints, and a summary of appropriate Management Actions for different parts of the HGL, as illustrated in a management cross-section (Figure 21).

Landscape functions and management strategies and actions are discussed further in Section 5, and in detail in *Guidelines for managing salinity in rural areas* (Wooldridge *et al.* 2015).

3.3 Using the HGL framework to manage landscape salinity

HGL provides a structure to help understand how salinity manifests itself in the landscape and how differences in salinity are expressed across the landscape.

A standardised reporting format describes the differences in salinity development and impacts in HGLs. Each management unit in an HGL encompasses a unique combination of landscape factors, such as soil, groundwater, geology, slope and climate, which show the source, transport and expression of salt in the landscape. A land manager can then identify where action should be taken for the most efficient and effective results. The format of this document, with maps, cross-sections and graphs, allows information to be easily communicated to landholders, Agency staff and the community.

HGL unit descriptions are a framework that spatially defines management areas, each with unique salinity situations requiring tailored management solutions through specifically assigned management actions. This framework facilitates an 'understanding of landscapes' and application of technically sound methods to target and prioritise limited funds to address natural resource management issues. This landscape understanding assists communities, landholders and organisations in placing 'the right activities in the right locations' within subcatchments.

The HGL framework is not limited to natural resource management (NRM) investment in salinity. Recent project activity has demonstrated that HGLs are useful tools to understand, target and set priorities for investment in addressing multiple NRM issues, such as:

- sodicity, acid sulfate soils, erosion
- wetland classification and definition
- surface and groundwater interaction in the landscape
- vegetation boundaries and biodiversity management units within landscapes;
- design of monitoring, evaluation and reporting (MER) data collection and analysis at local, catchment and state scales.

The simple process diagram in Figure 14 indicates the basic steps in the development of HGLs.

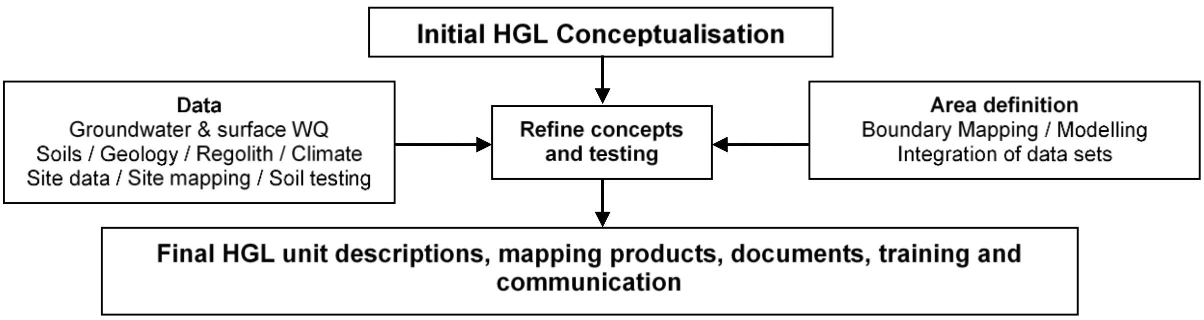

Figure 14 Steps involved in the generation of HGLs

4. Salinity Hazard within Capertee and Coxs River Valley Catchments

4.1 Land salinity

Four HGLs are rated as having High salt land impacts in the Capertee Valley:

- Marlyn Gate
- Horse Gap
- Nile
- Glen Alice.

These HGLs all have high proportions of salt land associated with saline geology units, restricted surface water movement and/or saline groundwater influence, and generate moderate volumes of sediment through active erosion. They are all underlain by layers of salt-bearing sediments from the Illawarra and Shoalhaven geological groups, which occur at different depths beneath the landscape. From these layers, dissolved salts are transported and precipitate at the surface as scalding, either in the low-lying landscape, or at points where the stratigraphy is locally exposed. Lateral movement of subsurface waters impeded by a soil texture change at the base of the talus slope may exacerbate saline discharge.

Marlyn Gate, eastern Horse Gap and Nile HGLs have benches formed of highly saline sediments in the lower landscape and on floodplains, which cause scalding on the surface (Figure 15). Nile HGL is influenced further by the upwelling of shallow, saline groundwater in the narrow valley.

Horse Gap HGL has ancient Shoalhaven Group sediments at the base of the colluvial slopes below the escarpment. Salts are dissolved and mobilised through the soils on the low-lying land where drainage is restricted, leading to scalding on the surface. The Permian Shoalhaven Group sediments act as a sponge, storing salts and water due to the depth and horizontal layering of the soils. Cycling of salts during the wetting and drying of these soils concentrates salts on the surface, leading to scalding.

Horse Gap HGL is in a bowl-shaped depression, which constricts movement of surface and saline groundwater. The bowl shape has a narrow exit channel which impedes water outflow, inducing water ponding in the valley and dissolution of salts in the underlying sediments. Scalds appear on the lower slopes and floodplains.

The HGLs with moderate and low proportions of salt land in the Capertee Valley (e.g. Dunville Homestead and Genowlan Mountain HGLs) and in the Coxs River (Lithgow) Valley (e.g. Pipers Flat and Angus Place HGLs) are positioned higher in the stratigraphy, such that the salty stratigraphic layers are deeper within the landscape and do not readily affect the surface layers. Other factors, including capping with non-salty stratigraphy (e.g. basalt caps over Shoalhaven Group sediments in Brogan View HGL) and the dominance of a non-salty stratigraphy at the surface (e.g. volcanic and limestone bedding in Port Macquarie Station HGL), hold salinity away from the surface and therefore produce non-saline water and landscapes.

To address salt land issues at a catchment scale the HGLs with the high and moderate impacts should be targeted with appropriate management strategies and actions. See the relevant HGL descriptions.

Figure 15 Scalded salt land and damaged water trough in foreground (Nile HGL) beside Umbiella Creek, Capertee Valley looking north
(Photo: Victoria Cull/DECCW)

Figure 16 indicates the areas on which salt land has an impact in both the Capertee Valley and the Coxs River Valley.

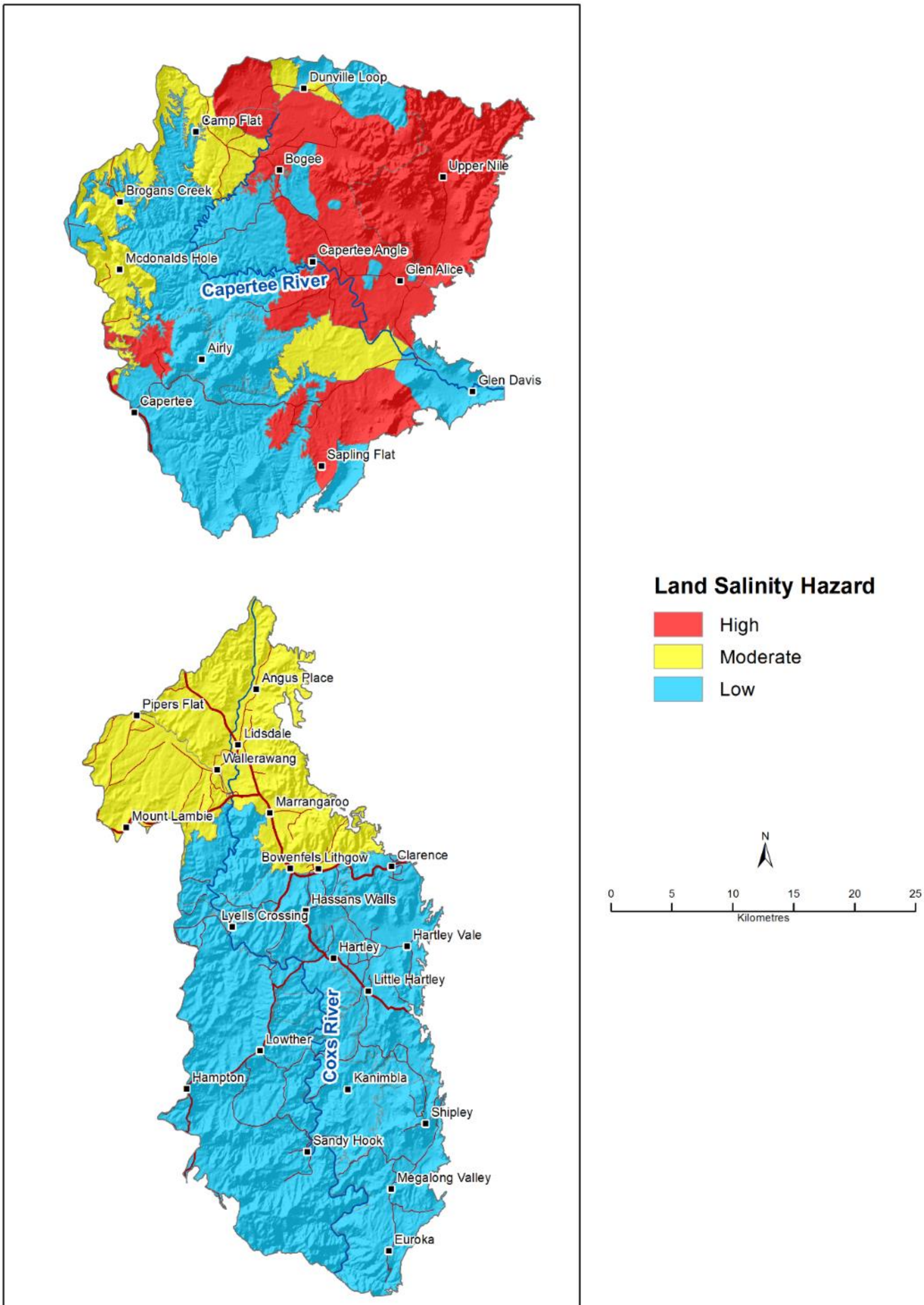

Figure 16 Salt land impacts in Capertee and Coxs River HGL units

4.2 Salt load

As indicated in Figure 17, two HGLs in the Capertee Valley have high salt load impacts:

- Horse Gap
- Nile.

These HGL areas are low lying, with good connection to streams. They also have landform features such as bowls, which function as concentration and evaporation areas. Revegetation of these specific areas will help reduce salt load.

In addition, in the Capertee Valley, five HGLs have moderate salt load impacts, and nine have low salt load impacts. The majority of HGLs in the Coxs River Valley have very low salt load impacts, with only a single HGL (Pipers Flat) having a moderate salt load impact. To address salt load issues at a catchment scale the HGLs with the high and moderate impacts should be targeted with appropriate management strategies and actions. Further sampling is required to quantify salt load impacts in the study area.

HGLs with moderate salt load export require specific management actions to balance salt export and water quantity impacts.

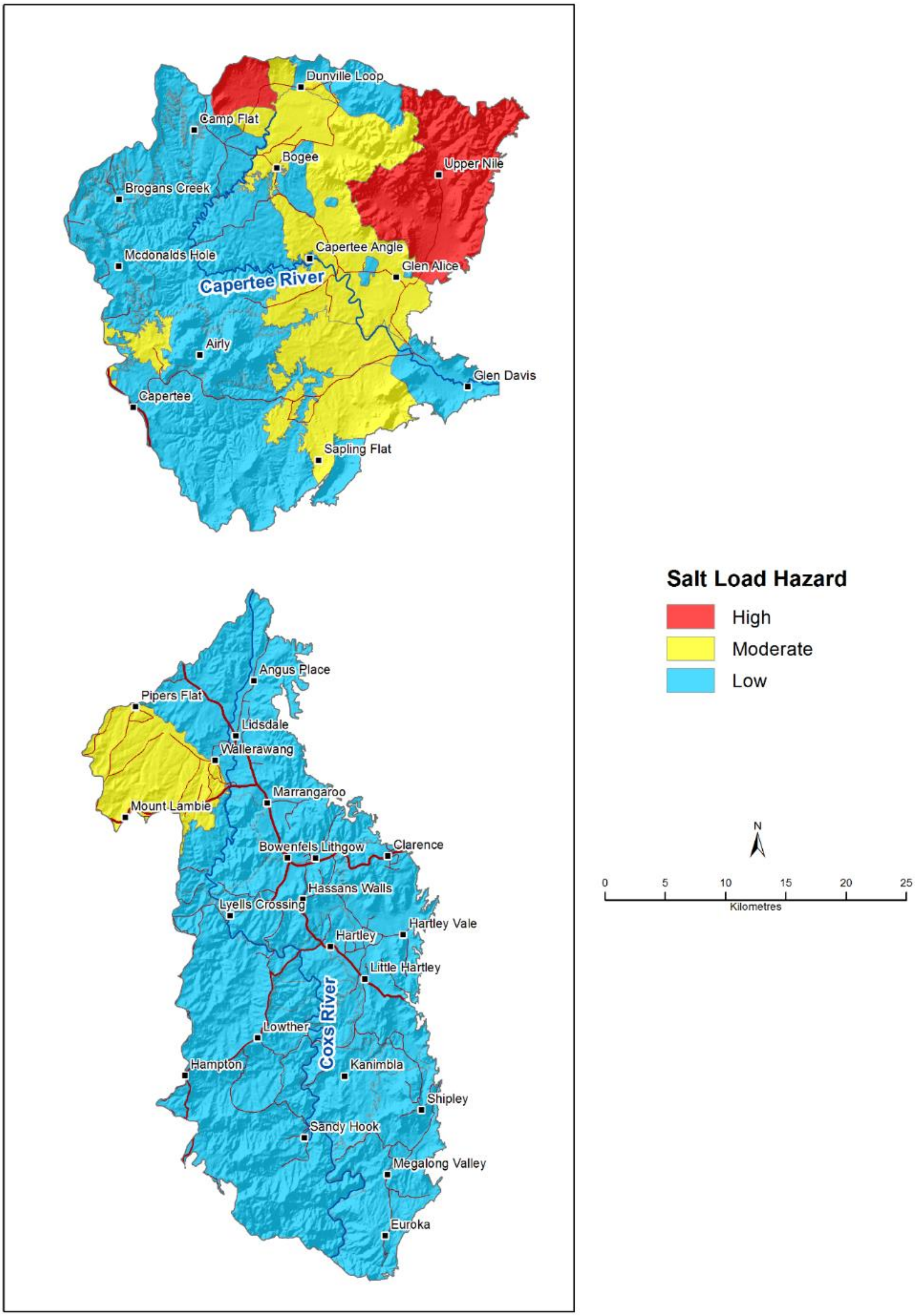

Figure 17 Salt load impacts in Capertee and Coxs River HGL units

4.3 Stream EC (water quality)

Streams were sampled several times over 18 months, with sampling conditions varying from dry for an extended prior period, to light rainfall during the week before the survey. EC records were previously collected during high flows in the Capertee Valley and contributed to an understanding of the salinity of larger rainfall events.

Dilution effects from runoff generated by fresh rainfall were generally low, as all streams sampled during the 18 month period were at base-flow or had falling flow levels, predominantly representing ground water salinity levels for the region. Due to these conditions, some ephemeral streams had become sporadic. Further routine sampling will add substantially to data confidence and indicate rising or falling trends in EC.

As can be seen in Table 7, three HGLs in the Capertee Valley have been rated as having high water quality impacts. These are:

- Dunns Farm
- Nile
- Glen Alice.

No HGLs in the Coxs River Valley are rated as having high water quality impacts. Records of EC levels in the Coxs River catchment indicate high quality, relatively fresh water throughout.

The moderate water quality impact HGLs require careful consideration of the balance between water quality and quantity.

A total of six HGLs have low water quality impacts in the Capertee Valley, and all eight HGLs in the Coxs River (Lithgow) Valley have a low water impact. These HGLs are generally in the higher rainfall zone (near the catchment divide in the Capertee Valley) and are important water sources and dilution areas. They have specific management implications at catchment level. See the relevant HGL descriptions.

To address water quality issues at a catchment level all HGLs must be considered. High water quality impact HGLs are sources of high EC water. Moderate water quality impact HGLs can be either a source of high EC water or a potential dilution flow, depending on rainfall events and catchment context. Low impact HGLs are important water sources and important for dilution flows and must be maintained as such (e.g. HGLs of the Coxs River area).

Although based on limited field data, HGLs in the high water quality impact category have high measured EC values. It should be noted that the spot sampling was undertaken during drought conditions and on an irregular basis. Some reference was made to historical records taken from *ad hoc* sampling in the mid-1990s as part of an Electromagnetic Survey Project conducted in the Dunville Loop area by the former DLWC. Some sparse landholder data were also sourced from sporadic readings through the 1990s.

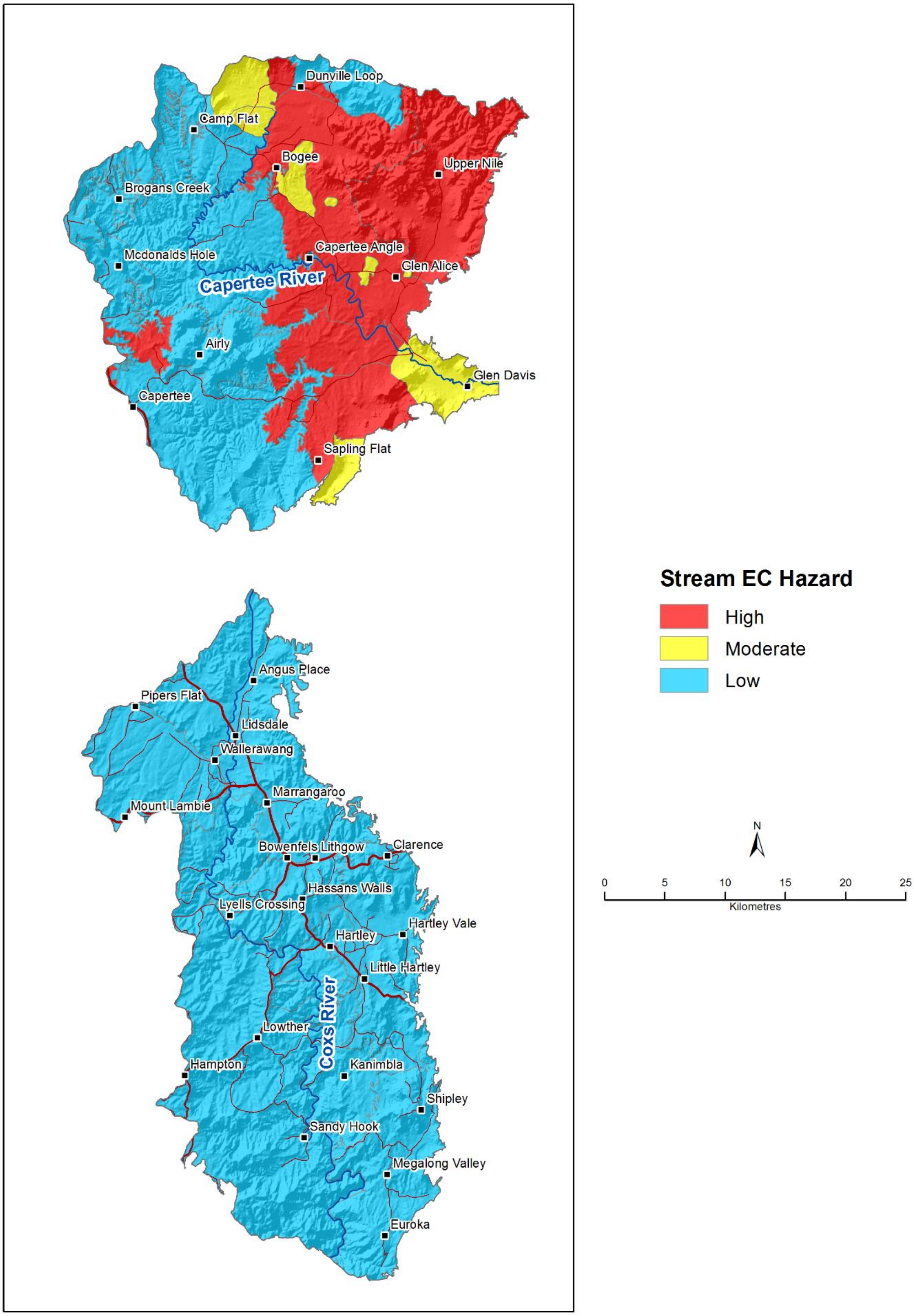

Figure 18 Water quality (EC) impacts in Capertee and Coxs River HGL units

4.4 Overall hazard

Overall salinity hazard in the Capertee and Coxs River Valleys is defined using five classes (Figure 19):

- **Very high –** demonstrated on-site and off-site impacts. Large areas of land and many flow lines examined in the course of this study showed salinity.
- **High –** demonstrated on-site and off-site impacts, but of a lesser severity than the Very High hazard grouping. A number of flow lines examined in the course of this study exhibited salinity. It was mostly of a cyclic nature (seasonal) and does not impact always.
- **Moderate –** some on-site impacts and limited off-site impacts, with moderate to low water quality impact. Pipers Flat HGL has salty coal measures in the stratigraphy close to the surface, increasing the likelihood of salinity expression. An impediment to drainage – a substantial roadway – runs transversely along the lower section of the HGL and combines with natural conditions to produce salinity symptoms under certain conditions.
- **Low –** some on-site impacts and low off-site impacts. These HGLs typically contribute fresh water.
- **Very low –** nil to very low on-site and off-site impacts. These constitute the majority of HGLs in the Coxs River area. Salinity was not observed in these units.

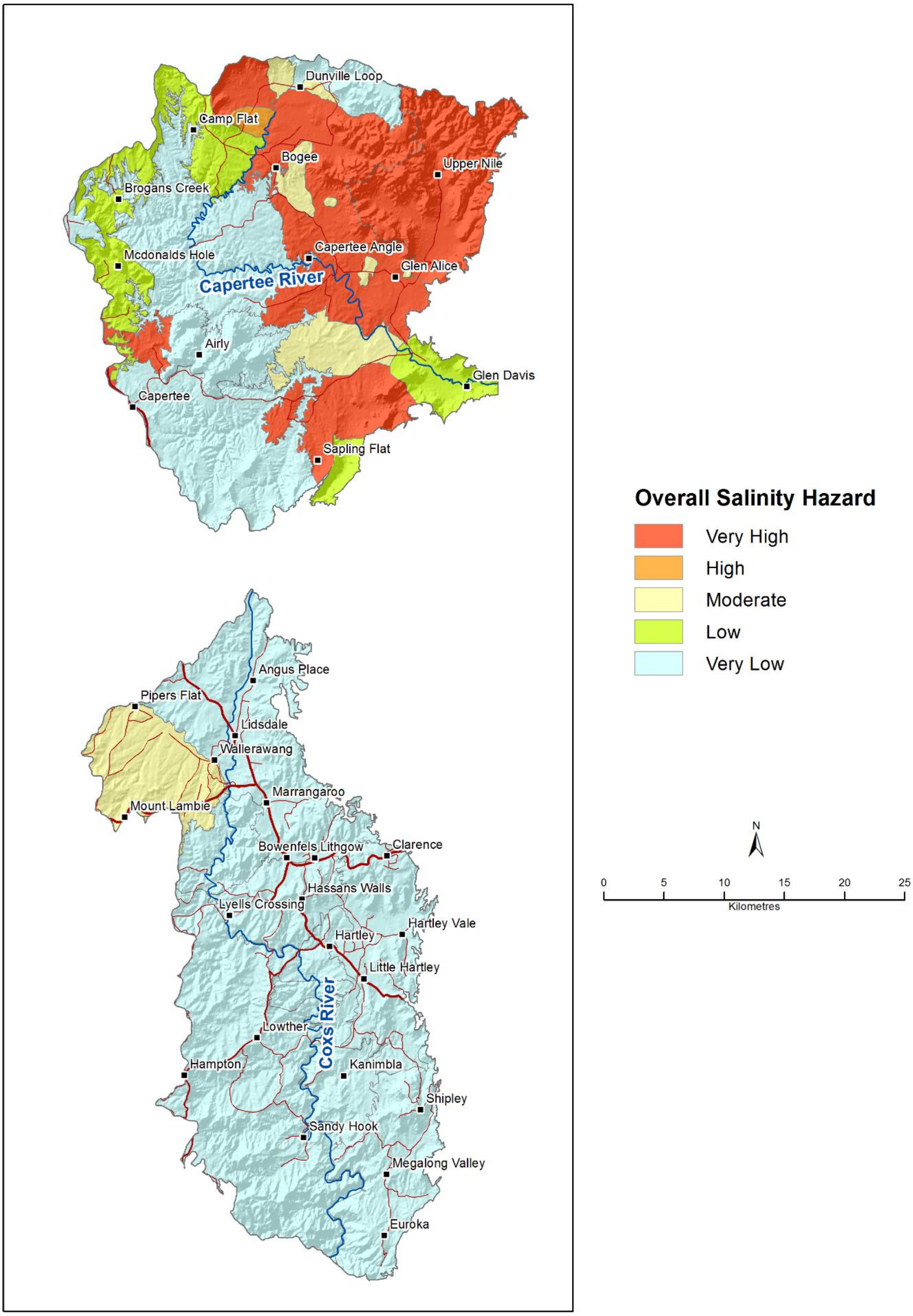

Figure 19 Overall salinity hazard impacts in Capertee and Coxs River HGL units

For interpretation purposes the catchment impacts are summarised in Table 7.

Table 7 Summary of salinity impacts for each HGL in the Capertee and Coxs River Valleys

HGL	Land Salinity Impact	Salt Load Impact	Stream EC Impact	Overall Salinity Hazard
Capertee				
Bourbin Hills	Low	Low	Moderate	Moderate
Brogan View	Low	Low	Low	Very Low
Dunns Farm	Moderate	Moderate	High	Moderate
Dunville Homestead	Low	Low	Low	Very Low
Genowlan Mountain	Low	Low	Low	Very Low
Glen Alice	High	Moderate	High	Very High
Glen Davis	Low	Low	Moderate	Low
Horse Gap	High	High	Moderate	Very High
Marlyn Gate	High	Moderate	Moderate	High
Mount Marsden	Moderate	Low	Low	Low
Nile	High	High	High	Very High
Port Macquarie Station	Low	Low	Low	Very Low
Coxs River				
Hartley	Low	Low	Low	Very Low
Angus Place	Moderate	Low	Low	Very Low
Pipers Flat	Moderate	Moderate	Low	Moderate
Hampton	Low	Low	Low	Very Low
Mid Coxs River	Low	Low	Low	Very Low
Mount Walker	Low	Low	Low	Very Low
Hassans Walls	Low	Low	Low	Very Low
Megalong valley	Low	Low	Low	Very Low

4.5 Sodicity

In the Capertee Valley, eroded sodic scalds are commonly found at mid-upper slope positions associated with key stratigraphic layers. In some areas of highly sodic/saline soil material, soil erosion has created significant landscape features (e.g. Bourbin Hills HGL). These areas are hard to revegetate due to the sodic nature of materials, steep slopes and shallow topsoils, which tend to be dense, hard setting, infertile and are a poor medium for seedling emergence and plant growth. Wind and water erosion removing the topsoil and sodic subsoils and expanding the degraded scalded areas accelerates vegetation loss. The exposure of the sodic subsoil materials has resulted in areas of severe rill and gully erosion. Very severe gully and rill erosion are features of the Marlyn Gate, Bourbin Hills and Nile HGLs.

There are several areas in the Capertee Valley where the combination of salinity and sodicity has caused soil erosion and the release of saline sediment. Many of the drainage lines and hillslopes are sodic. These areas require special management considerations and have been highlighted in the management section of the HGL templates (Appendix B).

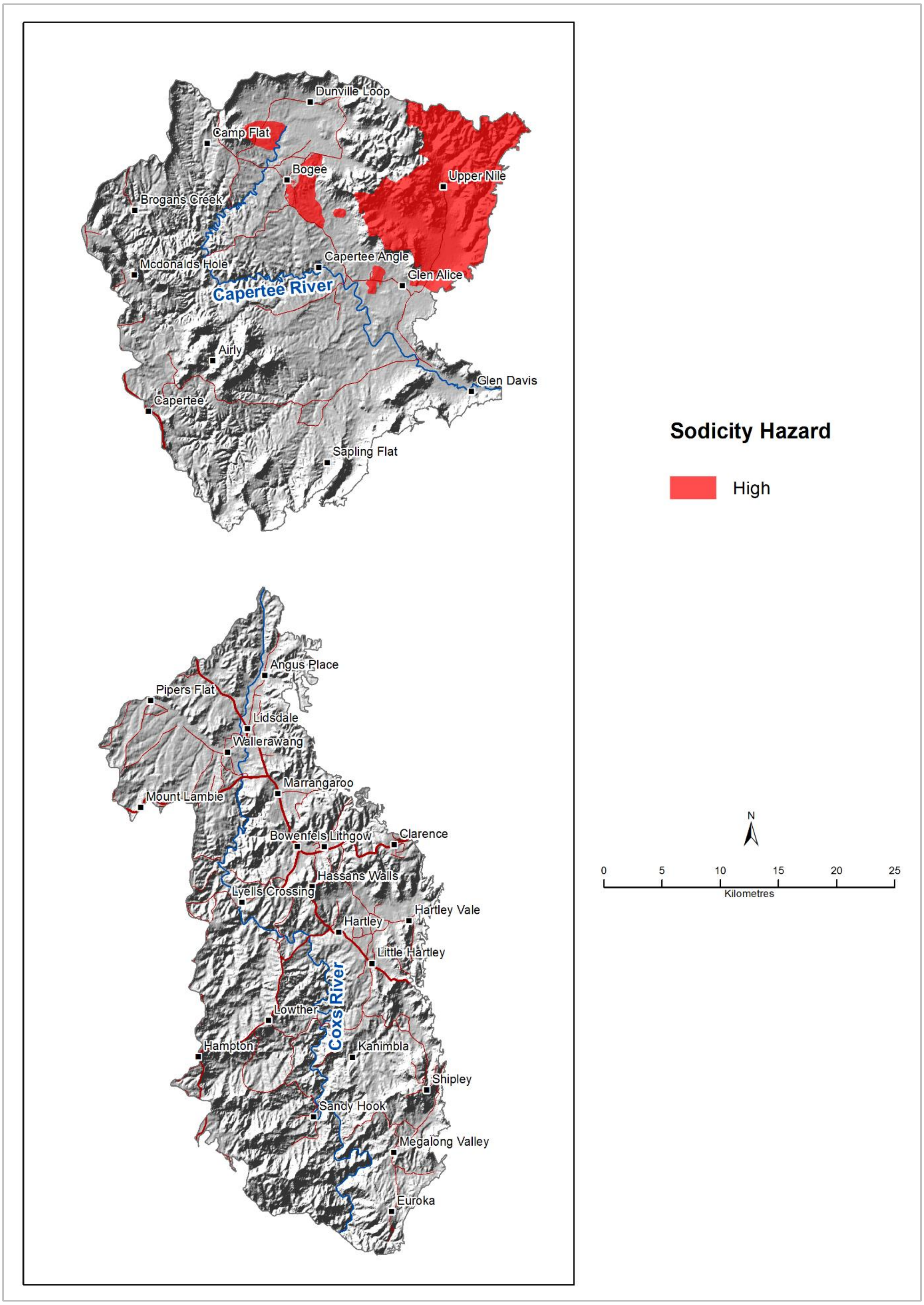

Figure 20 Sodicity hazard map

5. Landscape Management

This section discusses broad concepts and terminology used in the Management Options section of each HGL description. More detailed explanation is found in Wooldridge et al. (2015).

Accurate tailoring of appropriate land use for salinity management should be a core objective for natural resource agencies and land managers. It requires a technique for matching appropriate land use to the most suitable locations for optimal management results. This is the aim of this document and the complementary management guidelines.

At the local scale, the HGL mapping hierarchy identifies landscape facets (e.g. hill crest, mid slope and lower slopes) which can be linked to specific land management actions. Where the HGL concept is applied to salinity management, the mapping units show differences in salinity and hydrological characteristics, which invariably reflect an integration of geology, regolith, landform, climate and native vegetation.

5.1 Management areas

Management areas are defined as areas of land within an HGL that can be uniformly managed. They enable the link between landscape and targeted management and operate at the scale of landform facets (crest, upper slopes, footslopes, floodplains, etc.) (NCST 2009). For ease of comparison, management areas have been standardised (Table 8).

Table 8 HGL management areas

Management Area	Description
MA1	Crest or ridge
MA2	Upper slope – erosional
MA3	Upper slope – colluvial
MA4	Mid slope
MA5	Lower slope – colluvial
MA6	Rises
MA7	Saline site
MA8	Structurally controlled saline sites
MA9	Alluvial plains
MA10	Alluvial channels

The management area concept allows a complex suite of management actions to be directed to the appropriate part of a landscape. Management areas can be represented spatially on a map, or on the conceptual cross-section for the individual HGL (Figure 21). The management areas are based in part on the terminology used in the Australian Soil and Land Survey Field Handbook (NCST 2009).

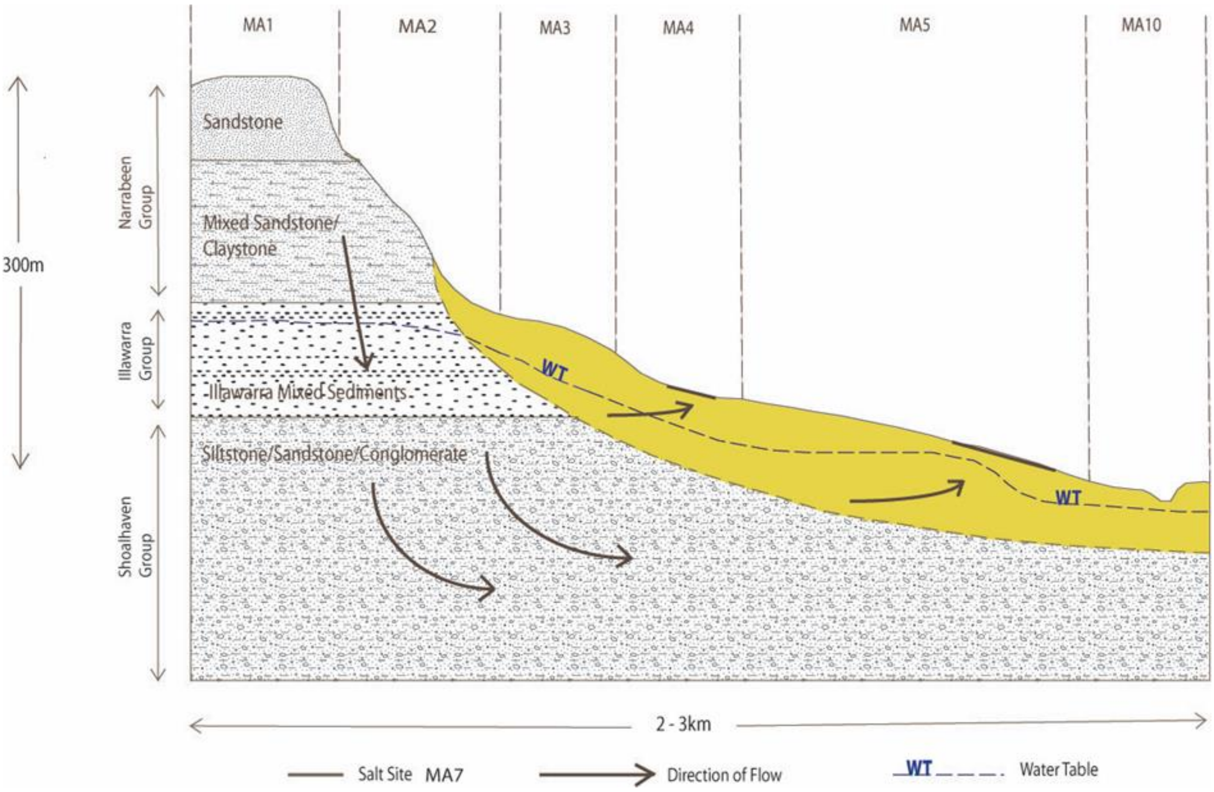

Figure 21 An example of an HGL conceptual cross-section (Dunns Farm) showing the shape of the landscape and key landscape features such as regolith, salt outbreaks and water flow paths. Management areas are assigned to specific landform elements

5.2 Management framework

The management framework is a way to assign optimal management actions to discrete parts of the landscape. The framework identifies the relevant landscape function and appropriate management strategy. The location and specific nature of the management actions are then defined at the local scale using management area concepts. The management framework can be applied to most landscape mapping systems.

The following sequential structure is used in each HGL unit:

landscape function > management strategy > management action

Each of these is discussed below.

Different management actions are applied to different parts of the landscape (management areas). Typically, the landscape function level corresponds with the catchment (up to 1:250 000 scale); management strategy corresponds with the landscape (approximately 1:100 000 scale) and management area corresponds to the facet (up to 1:10 000 scale). Once biophysical characteristics are recognised and organised using this structure the management actions for each management area can be selected (Figure 22).

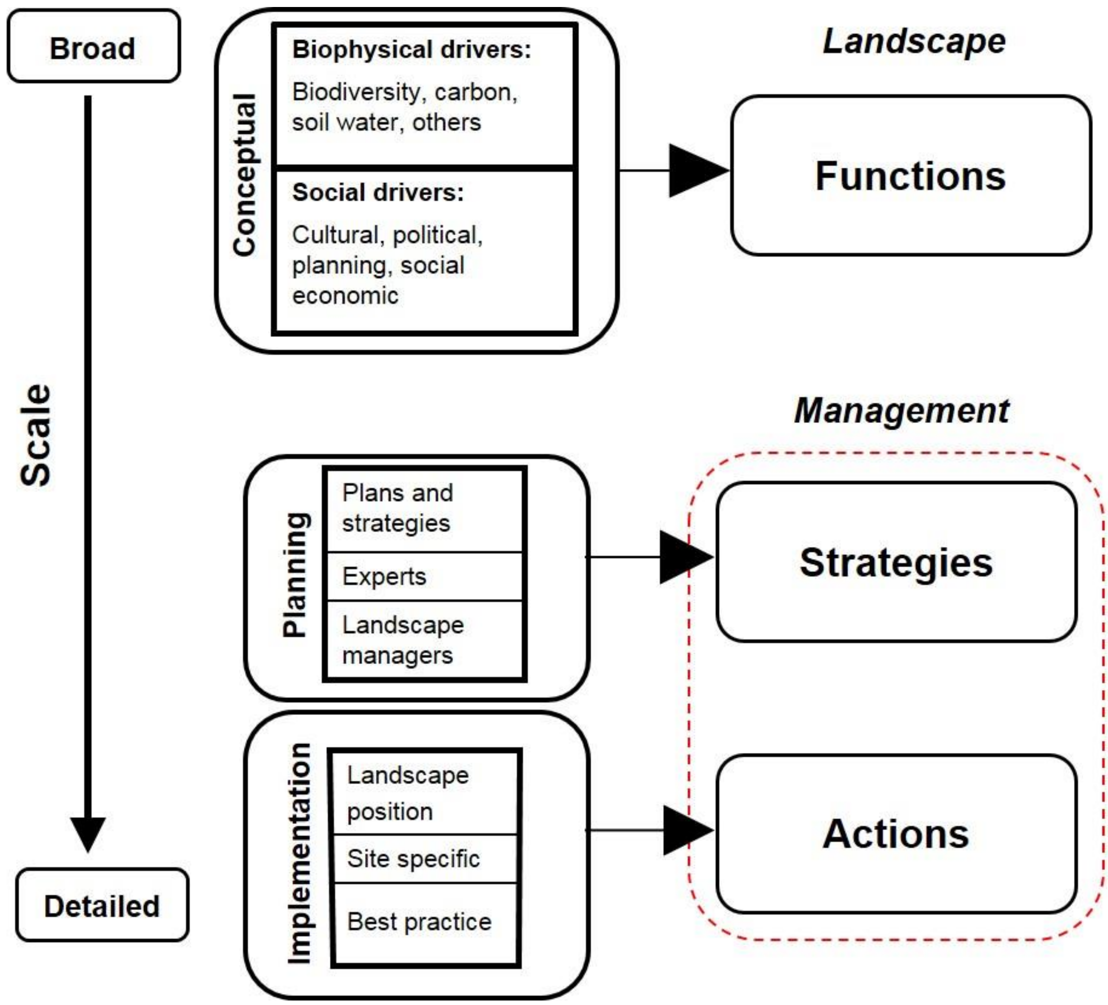

Figure 22 Scale and level of landscape functions and management strategies and actions used in HGLs

5.2.1 Landscape function

Landscape function is the highest order within the hierarchical HGL structure. Functions are inherent biophysical characteristics of a landscape which impact upon catchments (Table 9) and impact beyond the HGL. Effective salinity management involves understanding how landscape functions are maintained, improved or degraded. An HGL may provide one or more functions in a catchment.

Landscape function can also be used to define priority in a risk determination process. For example, a landscape may have a priority as a fresh water supply and hence, from Table 9, landscape functions A, B and C are relevant and can be mapped. Similarly, a landscape can have a priority based on soil-related hazards, for which landscape functions H and I are important.

Refer to Wooldridge et al. (2015) for further information on landscape function.

Table 9 Landscape functions

Function	Description
A	The landscape provides fresh water runoff as an important water source.
B	The landscape provides fresh water runoff as an important dilution flow source.
C	The landscape provides important base flows to local streams.
D	The landscape generates salt loads which enter streams and are redistributed in the catchment.
E	The landscape receives and stores salt load through irrigation or surface flow.
F	The landscape generates high salinity water that does not enter local streams.
G	The landscape contains important land assets (including infrastructure and high value agricultural land) on which salinity processes impact.
H	The landscape contains a high hazard for generating sodic and saline sediments.
I	The landscape contains a high hazard for acid sulfate processes.

It is important to understand that application of inappropriate management strategies and actions can negatively impact on landscape function and overall landscape resilience.

5.2.2 Management strategies

Management strategies aim to maintain or improve landscape functions. One or more strategies may apply to any landscape. The 11 salinity management strategies are outlined in Table 10. As previously mentioned, recharge refers to water that percolates through to groundwater. Increased recharge can lead to rising water tables and mobilise salt stored in the soil. Discharge refers to groundwater seeping into streams or to the land surface. On the land, it is often expressed as areas of waterlogging. Salt sites may occur as a result of evaporation.

Management strategies guide activities in a particular HGL. The actions associated with them recognise the need for diffuse and/or specific activities within the landscape to address salinity issues. The priority of management strategies will vary between HGLs.

Refer to Wooldridge et al. (2015) for further information on management strategies.

Table 10 Management strategies

Strategy	Description
1	Buffer the salt store – keep it dry and immobile.
2	Intercept shallow lateral flow and shallow groundwater.
3	Stop discrete landscape recharge.
4	Rehabilitate and manage discharge.
5	Increase agricultural production to dry out the landscape and reduce recharge.
6	Dry out the landscape with diffuse actions over most of the landscape.
7	Access and use groundwater to change the water balance.
8	Maximise recharge to dilute water tables and minimise runoff to streams.
9	Minimise recharge in lower parts of the landscape and maximise runoff to streams.
10	Maintain or maximise runoff.
11	Manage and avoid acid sulfate hazards.

5.2.3 Management actions

Management actions deliver management outcomes. Detailed and specific management actions are assigned to appropriate management areas, ensuring that the management options are applicable to all parts of the landscape.

The dynamics of a management action may vary. Sometimes the action is very suitable for delivering one strategy, but unsuitable for a different strategy. Management actions are assessed for suitability and priority for landscape salinity management. A management action which is suitable for salinity management in one landscape may be unsuitable or ineffective in another. Combinations of management actions are tailored in accordance with the management strategy objectives. There are more than 50 defined management actions; the list is not exhaustive and new management actions or land management techniques are added as required. New techniques, technologies or discoveries offer new options. New localities offer new challenges that may require management actions not yet identified.

Refer to Wooldridge et al. (2015) for further information on management actions for rural areas.

The rural management actions shown in Table 11 have been grouped as follows:

- VE Vegetation for ecosystem services
- VP Vegetation for production
- FS Farming systems
- SA Soil ameliorants
- E Engineering
- IS Irrigation systems
- SR Salt land rehabilitation
- AS Acid sulfate hazards.

Table 11 Groups of rural management actions

Management Action Group	Code	Management Action
Vegetation for ecosystem services	VE1	Establish and manage blocks of trees to reduce recharge.
	VE2	Establish and manage trees to intercept lateral groundwater flow.
	VE3	Maintain and improve existing native woody vegetation to reduce discharge.
	VE4	Maintain and improve riparian native vegetation to reduce discharge to streams.
Vegetation for ecosystem services	VE5	Establish and manage trees that are integrated into farming logistics to reduce recharge.
	VE6	Revegetate non-agricultural land with native species to manage recharge.
	VE7	Use targeted planting of trees to buffer salt stored in geological layers.
	VE 8	Maintain and improve existing native woody vegetation to protect current landscape hydrology.
	VE 9	Manage total grazing pressure to maintain and improve native vegetation for hydrology outcomes.
	VE 10	Manage animal impact on sensitive areas for hydrology outcomes.
Vegetation for production	VP1	Improve grazing management of existing perennial pastures to manage recharge.
	VP2	Establish and manage perennial pastures to manage recharge.
	VP3	Establish and manage perennial pastures to intercept shallow lateral groundwater flow.
	VP4	Maximise agricultural production from pastures by input of additional ameliorants to manage recharge.
	VP5	Improve grazing management to improve or maintain native pastures to manage recharge.
	VP6	Establish and manage blocks of perennial forage shrubs to manage recharge.
	VP7	Establish commercial forestry to manage recharge.
	VP8	Establish and manage farm scale forestry integrated into farming logistics to reduce recharge.
	VP9	Establish and manage perennial horticulture to manage recharge.
Farming systems	FS1	Implement pasture cropping with annual cereals in perennial pastures to manage recharge.
	FS2	Maximise agricultural production by using ameliorants in annual cropping systems to manage recharge.
	FS3	Implement rotational cropping with a perennial pasture component to manage recharge.

Management Action Group	Code	Management Action
	FS4	Implement opportunity cropping with annual crops and green manures to manage recharge.
	FS5	Deep rip soil to improve soil structure and manage recharge.
	FS6	Implement zero-till farming systems to increase soil water storage, soil water use and to reduce recharge.
	FS7	Implement controlled traffic farming systems to increase soil water storage, soil water use and to reduce recharge.
	FS8	Implement no-till farming systems to increase soil water storage, soil water use and to reduce recharge.
Farming systems	FS9	Implement reduced-till farming systems to increase soil water storage, soil water use and to reduce recharge.
	FS10	Implement direct-drill farming systems to increase soil water storage, soil water use and to reduce recharge.
	FS11	Use green manures and manure crops to increase soil water storage, soil water use and to reduce recharge.
Soil ameliorants	SA1	Ameliorate soil sodicity by adding gypsum to increase plant water use and reduce recharge.
	SA2	Ameliorate soil sodicity by adding lime to increase plant water use, reduce recharge and manage discharge sites.
	SA3	Ameliorate soil acidity by adding lime to increase plant water use, reduce recharge and manage discharge sites.
	SA4	Improve soil health by applying biological agents to the soil to increase plant water use, reduce recharge and manage discharge sites.
	SA5	Improve soil health by applying compost to increase plant water use, reduce recharge and manage discharge sites.
Engineering	E1	Use groundwater to supplement or replace surface water for farm stock.
	E2	Divert surface water to increase recharge in low lying areas and minimise runoff.
	E3	Construct agricultural earthworks to maximise freshwater runoff and reduce recharge in low areas.
	E4	Implement groundwater pumping and disposal.
	E5	Manage stream flow to create dilution flows in regulated rivers.
	E6	Manage flow cycles of rivers to periodically produce dry supply channels and streams.
	E7	Install leaky weirs to slow streams and increase freshwater recharge.
	E8	Construct diversion banks to connect streams with back plains to increase freshwater recharge.

Management Action Group	Code	Management Action
Irrigation systems	IS1	Manage on-farm irrigation to achieve best practice.
	IS2	Manage irrigation supply systems to achieve best practice.
	IS3	Establish effective effluent disposal systems specific to site conditions.
Salt land rehabilitation	SR1	Fence and isolate salt land and discharge areas to promote revegetation.
	SR2	Establish and manage salt land pasture systems to improve productivity.
	SR3	Establish forestry systems on salt land to improve productivity.
Salt land rehabilitation	SR4	Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation.
	SR5	Establish and manage salt land grazing systems based on forage shrubs to improve productivity.
	SR6	Pond water on dry scalds to promote revegetation.
	SR7	Reduce animal impact on scalds by providing mineral supplements to stock.
	SR8	Mulch sites to reduce evaporation and promote pasture growth.
	SR9	Mulch sites using tactical animal impact.
Acid sulfate hazards	AS1	Improve or maintain the hydrological regime to keep acid sulfate soil saturated.
	AS2	Isolate and improve acid sulfate soil sites.

5.2.4 High hazard land use

Sixteen high hazard management actions (discouraged land uses – DLU) are in Table 12. They may make salinity problems worse and override positive salinity management actions, and should be actively discouraged.

High hazard management actions are assessed for their impact and their priority for salinity management. An action which may result in immediate and severe salinity impacts in one landscape may be less damaging in another. The dynamics of an action may vary. Sometimes the action is very suitable for implementing a strategy, but may be unsuitable for a different strategy.

The list of high hazard land uses in Table 12 is not exhaustive and new management actions or land management techniques can be added after their salinity impact has been assessed.

Refer to Wooldridge et al. (2015) for further information on high hazard land uses.

Table 12 Summary of high hazard land use actions

Code	Management Action
DLU1	Long fallows in farming systems.
DLU2	Poor management of grazing pastures.
DLU3	Annual cropping with annual plants.
DLU4	Clearing and poor management of native vegetation.
DLU5	Farm dams in flow lines.
DLU6	Reducing runoff from fresh surface water catchments.
DLU7	Locating infrastructure on discharge areas.
DLU8	Poor soil management – tillage causing poor structure.
DLU9	Poor soil management – chemical and biological.
DLU10	Poor soil management – loss of surface soil layers.
DLU11	Deep ripping of soils to maximise water infiltration to subsoil.
DLU12	Flat contour banks.
DLU13	Irrigation using inefficient on-farm water delivery practices.
DLU14	Poor targeting of land suitable for irrigation.
DLU15	Loading of soils with salt through irrigation and flow management.
DLU16	Construction of drains to lower water tables.

5.3 Land management for salinity in the Capertee and Coxs River Valleys

This section provides information for salinity management in the Capertee and Coxs River Valleys. It complements management strategies and actions discussed previously.

5.3.1 Key factors in land management for salinity

Salinity processes are influenced by various factors:

- water use characteristics of the vegetation
- climate and hydrogeological characteristics of the landscape
- volume of recharge that occurs and how this recharge responds to changes in land management practices

Actions that impact on water use by vegetation or on water stored in the soil will influence recharge across the landscape:

- salinity processes are usually diffuse across a landscape. Management actions must be applied over a large proportion of a catchment to have impact.
- the design of management actions must allow for both continual and episodic recharge patterns. Like many environmental issues, salinity processes are not always linear. Climatic cycles over years and decades are linked to patterns of salinity processes.
- design of land management actions should consider extreme recharge and discharge events
- catchment scale salinity management should consider the surface hydrology of the landscape.

Specific management actions can be targeted when salinity processes are understood at the scale at which the action is to be applied. It is important to recognise that targeting comparatively small areas of a catchment may not significantly impact on salinity processes and outcomes for the broader catchment. Discharge management is an important part of subcatchment salinity management.

Table 13 outlines aspects of management for land salinity, salt load and water quality processes in the Capertee and Coxs River Valleys

Table 13 Management aspects of catchment scale salinity processes in the Capertee and Coxs River Valleys

	Land Salinity	Salt Load Export	Water Quality – Salt Concentration in Streams
Process	• Land becoming degraded – saline and eroded • Slowly spreading areas of degrading land.	• Large volume of salt moving down streams and rivers usually in high volumes of water at low concentration • Salt redistributed in the landscape through water flow and irrigation.	• High salinity concentration water moving through rivers and streams.
Major Areas	• Lower colluvial slopes, alluvial plains and rises in valleys.	• Generated in valley floors from specific landscapes (geologies) • Enhanced by constrictions in valley formations • Redistributed in riverine ecosystems.	• Time based: seen as events or spikes which last hours or days. On riverine floodplains, e.g. around the Umbiella Creek • Area based: certain landscapes express consistently high salinity which is less related to stream hydrographs.
Impacts	• Loss of on-site agricultural productivity • Loss of vegetation and ecosystems function • Erosion and decreased off-site water quality • Damage to infrastructure.	• Wetlands, floodplains and riverine ecosystems • Irrigation land • Urban irrigated areas.	• Point source water users: urban, agricultural and industrial • Riverine & wetland ecosystems • Infrastructure.

	Land Salinity	Salt Load Export	Water Quality – Salt Concentration in Streams
Management Aims	• Manage recharge in priority subcatchments • Slow rate of spread of existing sites • Fence and remediate existing sites • Minimise off-site impacts.	• Reduce load • Keep load where it is – diffuse in the landscape • Manage redistribution of salt load.	• Reduce peaks in salinity concentration Smooth out the hydrograph • Dilute saline flows with fresh water flows where possible.
Management Actions	• Rehabilitation of saline discharge sites • Minimise recharge through vegetation and land use in recharge areas.	• Minimise recharge through vegetation and land use in recharge areas of salt load generating landscapes • Manage redistribution of salt load to avoid negative impacts • Treat discharge through vegetation and land use to reduce negative impacts.	• Minimise recharge through vegetation and land use in high salinity generating landscapes • Use dilution flows in regulated catchments • Manage high salinity flows to avoid negative impacts • Point source extractors can avoid high salinity flows • Maintain and maximise runoff from freshwater generating areas.
High Impacts	**Capertee** • Marlyn Gate • Horse Gap • Nile • Glen Alice. **Coxs River** • None.	• Horse Gap • Nile. • None.	• Dunns Farm • Nile • Glen Alice. • None.
Moderate Impacts	**Capertee** • Mount Marsden • Dunns Farm • Glen Alice. **Coxs River** • Angus Place • Pipers Flat.	• Marlyn Gate • Dunns Farm • Glen Alice. • Pipers Flat.	• Marlyn Gate • Horse Gap • Bourbin Hills • Glen Davis. • None.

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Appendices

A1: **Capertee and Coxs River Valleys HGL Distribution**

A2: **Overall Salinity Hazard for Capertee and Coxs River Valleys HGL**

A3: **Capertee and Coxs River Valleys HGL Summary Table**

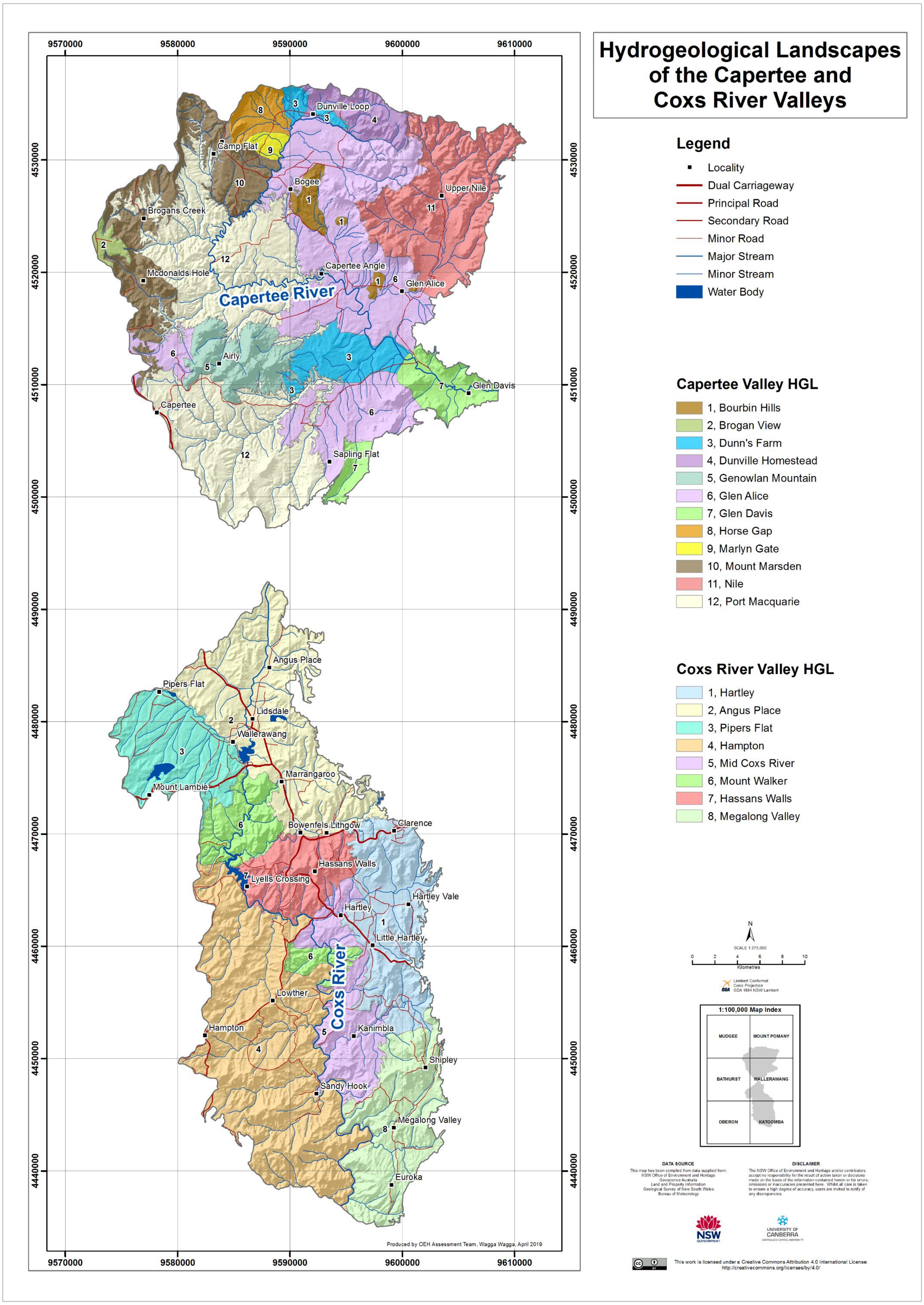
B: **Capertee and Coxs River Valleys HGL Unit Descriptions**

C: **Vegetation Communities**

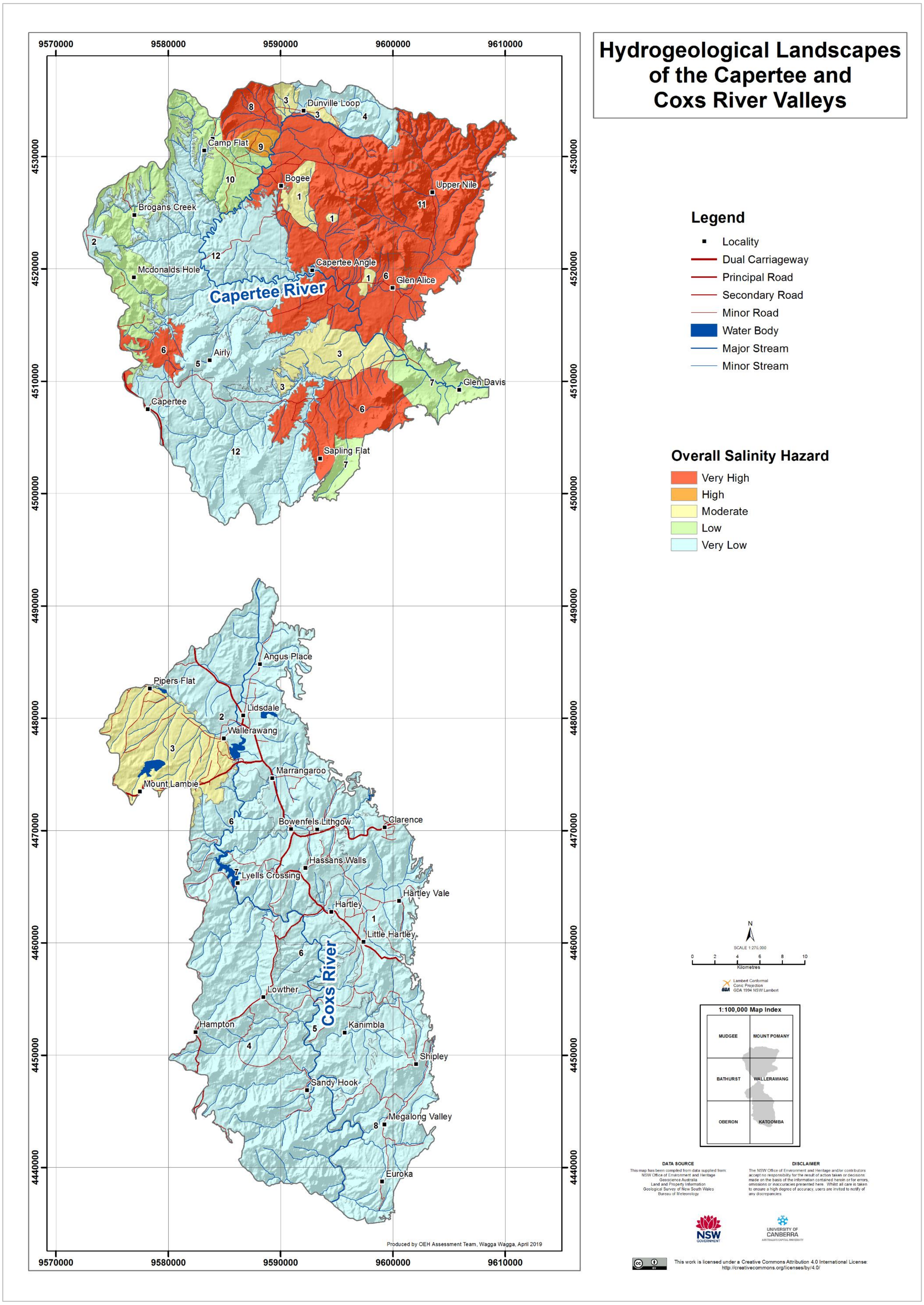
D: **Data Sources**

E: **Dataset Attribute Table Information and Colour Schemes**

Appendix A1: Capertee and Coxs River Valleys HGL distribution



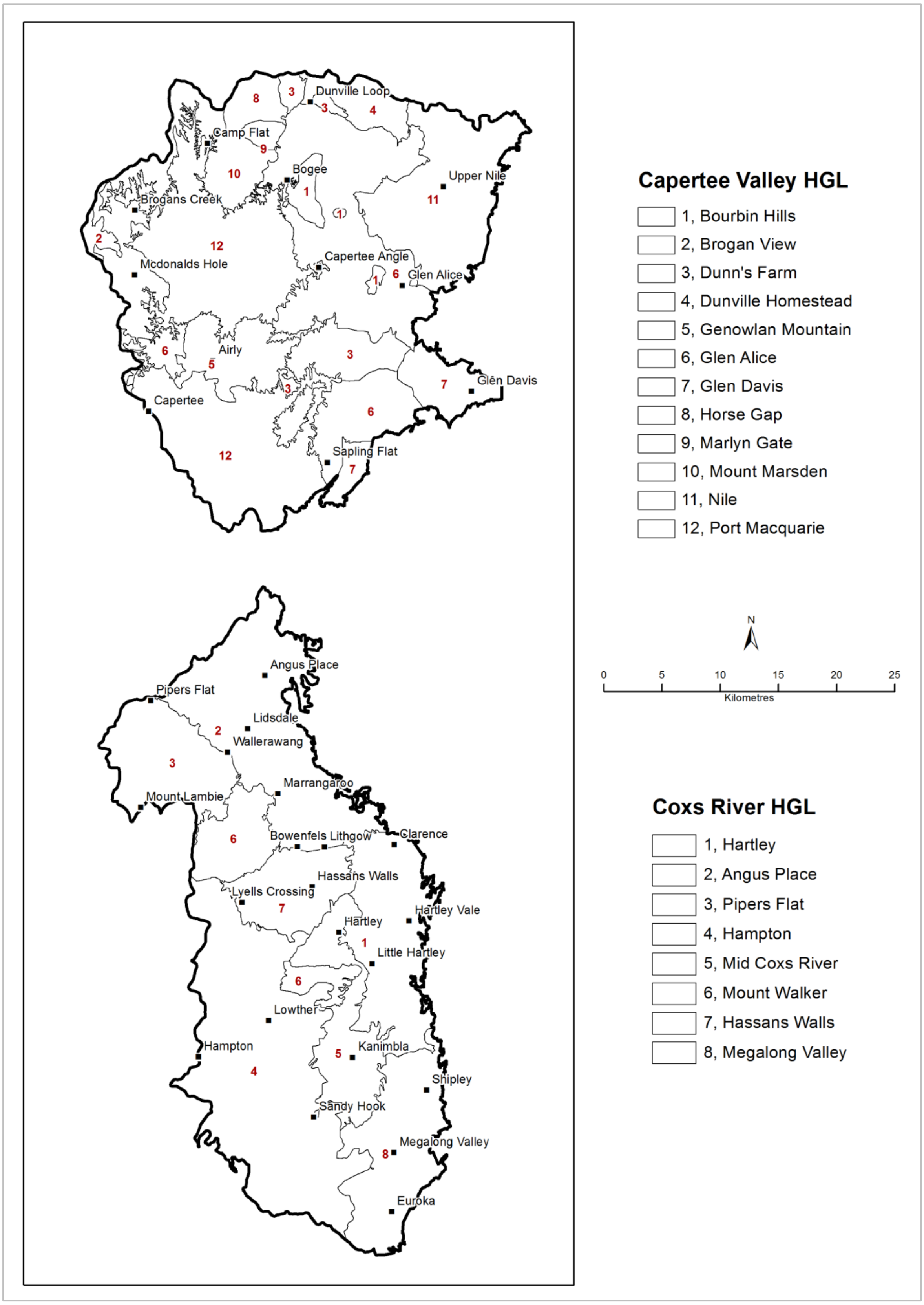
Appendix A2: Overall salinity hazard for Capertee and Coxs River Valleys HGL



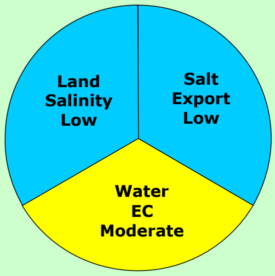
Appendix A3: Capertee and Coxs River Valleys HGL summary table

HGL No.	HGL Name	Land Salinity Impacts	Salt Export Impacts	Water EC Impacts	Sodicity	Salt store	Salt Availability	Impact	Likelihood	Overall hazard	Source Data Reliability	Landscape Function	Management Strategy
Capertee													
1	Bourbin Hills	Low	Low	Moderate	High	Moderate	Moderate	Significant	Moderate	Moderate	Medium	H	1
2	Brogan View	Low	Low	Low		Moderate	Low	Limited	Low	Very Low	Medium	A, B	1, 2, 4, 6, 7, 3
3	Dunns Farm	Moderate	Moderate	High		High	Moderate	Significant	Moderate	Moderate	Medium	D, E, F	4, 6, 1, 2
4	Dunville Homestead	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	8
5	Genowlan Mountain	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B	1, 4, 6
6	Glen Alice	High	Moderate	High		High	Moderate	Severe	High	Very High	Low	E, D, F	2, 4, 6
7	Glen Davis	Low	Low	Moderate		Low	High	Limited	Moderate	Low	Medium	E	8
8	Horse Gap	High	High	Moderate		High	High	Severe	High	Very High	Medium	D, E	2, 4, 3, 6
9	Marlyn Gate	High	Moderate	Moderate	High	Moderate	Moderate	Significant	High	High	Medium	D, E, H	1, 4, 6
10	Mount Marsden	Moderate	Low	Low		Low	Moderate	Significant	Low	Low	Medium	B	1, 4, 6
11	Nile	High	High	High	High	High	Moderate	Severe	High	Very High	Medium	C, D, E, F	1, 4, 6, 2
12	Port Macquarie Station	Low	Low	Low		Low	Low	Limited	Low	Very Low	Medium	A	10
Coxs River													
1	Hartley	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6
2	Angus Place	Moderate	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6
3	Pipers Flat	Moderate	Moderate	Low		Moderate	Moderate	Significant	Moderate	Moderate	Medium	A, B	10, 6
4	Hampton	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6
5	Mid Coxs River	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6
6	Mount Walker	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B	10
7	Hassans Walls	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6
8	Megalong Valley	Low	Low	Low		Low	High	Limited	Low	Very Low	Medium	A, B, C	10, 6

Appendix B: Capertee and Coxs River Valleys HGL unit descriptions



1. Bourbin Hills Hydrogeological Landscape

LOCALITIES	**Bourbin Hills**	
GEOLOGY SHEET	**Singleton 1:250 000**	
CONFIDENCE LEVEL	**Medium**	

OVERVIEW

The Bourbin Hills Hydrogeological Landscape (HGL) is a north-west trending group of landforms located in the centre of the Capertee Valley. The area receives >700 mm of rain per annum.

This low hill landscape stands out as a unique feature with very high erosion rates and has similarities with the Marlyn Gate HGL. Each has similar stratigraphy and is poorly vegetated and severely eroded.

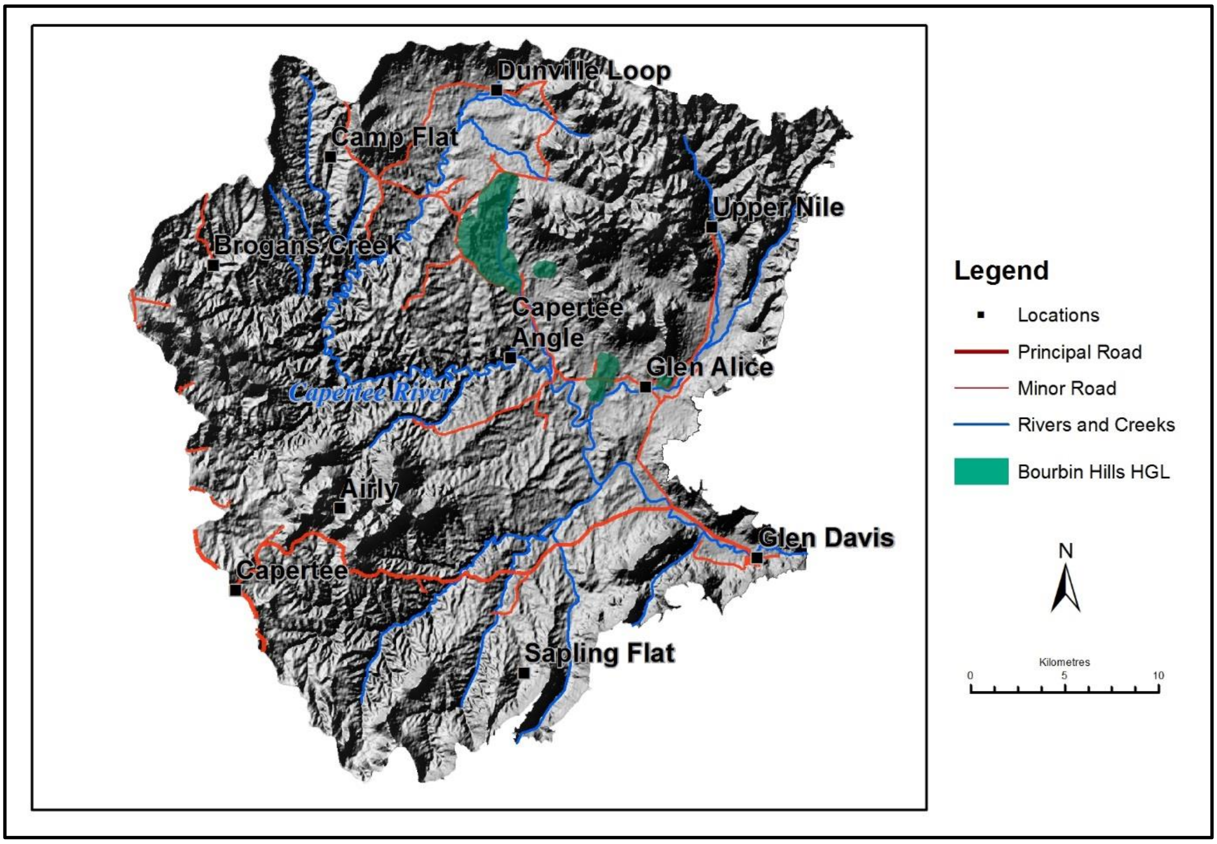


Figure 1: Bourbin Hills HGL location map.

Bourbin Hills HGL is characterised by flat-lying Permian shales of the Nile Subgroup (Illawarra Group) within the Capertee Valley at Bourbin Hills and Glen Alice. Typical lithologies for this HGL are shales with sandstone, claystone and minor coal. This is underlain by siltstone, sandstone and conglomerate of the Shoalhaven Group, obscured by the overlying sediments in this HGL. This landscape features a number of isolated areas of poorly vegetated, severely eroded low hills and rises. These features appear to be outliers of shaly (Nile Subgroup) rocks that may once have extended across the valley floor but are now represented by these remnant landforms. Moderate to deep weathering of these landforms has resulted in highly dispersive soils that are easily eroded.

There may be limited penetration of water into these landforms, because of the dispersive nature of the soils, and therefore a great deal of the water will run off as surface flow, causing erosion. Any water that percolates through the soil zone will preferentially move through the fractured sedimentary rock via structures (bedding, joints, fractures, faults) until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Some of this groundwater will mobilise salts, but because less water is able to penetrate the landform, than runs off, salt mobilisation is in this landscape is limited. A soil texture change (from fractured rock to silty clay soils) at the change in slope may impede lateral movement of subsurface waters. Lower in the landscape water moves laterally through the alluvial materials, and may emerge at the land surface, particularly in wetter periods.

In this HGL, small to moderate (<2 ha) seasonal saline scalds are found lower on the colluvial slopes where there is a texture contrast and a slope change and on alluvial plains (<1 ha). There is a low to moderate expression of salt in this HGL and a corresponding low salt load to streams and moderate EC values. Severe erosion is seen on poorly vegetated low hills and rises with dispersive sodic soils (Soloths) and this causes off-site siltation in streams.

Landscape limitations and hazards include severe rill, sheet and gully erosion on dispersive soils resulting in off-site siltation. Small saline scalds (<0.5 ha) are present at changes in slope and on adjacent alluvial plains associated with seasonal waterlogging.

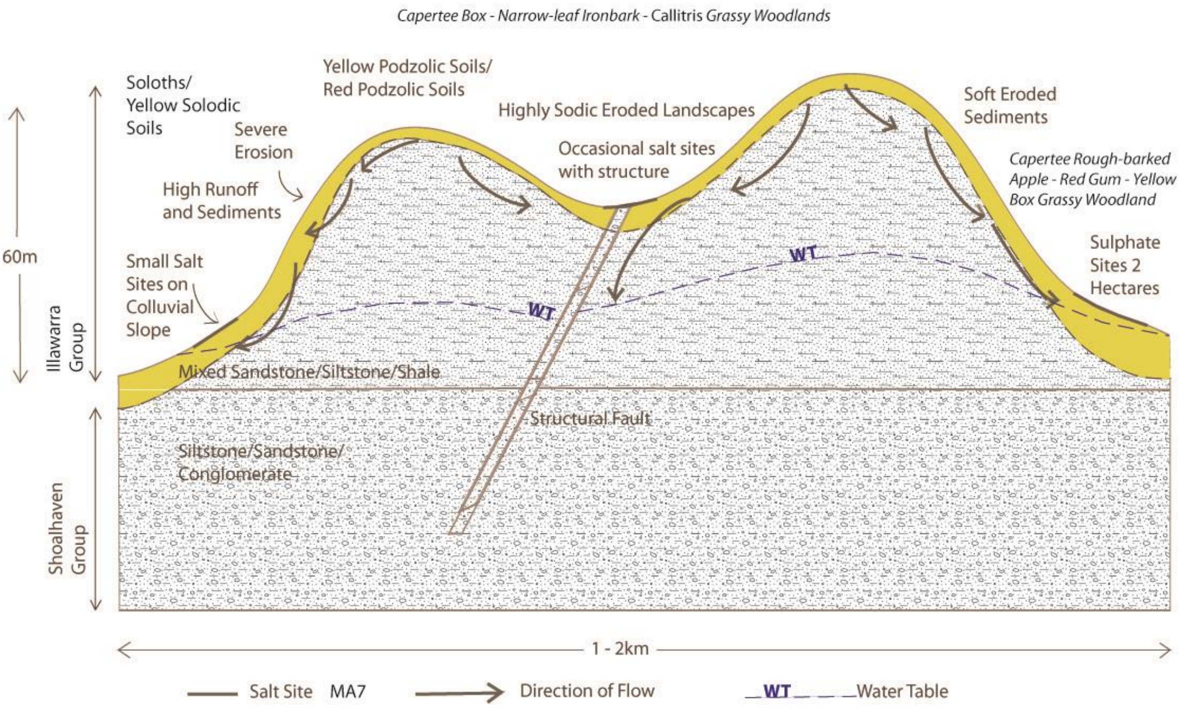


Figure 2: Conceptual cross-section for Bourbin Hills HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Bourbin Hills HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity low. Small seasonal saline sites (<0.5 ha) form on lower colluvial slopes, behind structural barriers and on adjacent alluvial plains (<1 ha). These low hills and rises are sodic and highly erodible. Vegetation on these outliers is characterised by sparse Kurrajong (*Brachychiton* sp.) stands.
Salt Load (Export)	Low levels of salt are exported from the landscape.
EC (Water Quality)	Moderate (EC 0.8–1.6 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Bourbin Hills HGL has moderate mobility. There is a moderate salt store that has moderate availability (Table 2).

Table 2: Bourbin Hills HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store		**Bourbin Hills**	
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Bourbin Hills HGL is moderate. This is due to the moderate likelihood that salinity issues will occur and that they would have potentially significant impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Bourbin Hills HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence		**Bourbin Hills**	
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from the Dunville Loop Road looking south, showing the eroded hills (in the background) of the Bourbin Hills HGL (Photo: DECCW/Rob Muller).

Photo 2: View from the Dunville Loop Road looking south-west overlooking Bourbin Hills (in the background) of the Bourbin Hills HGL (Photo: DECCW/Luke Taylor).

Photo 3: View from Glen Alice Road facing north, showing rounded and eroded hills (part of the smaller section of the unit to the south) of the Bourbin Hills HGL (Photo: DECCW/Victoria Cull).

Table 4: Summary of information used to define Bourbin Hills HGL.

Lithology *(Rasmus et al.1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian period. Key lithologies include: Illawarra Group (Nile subgroup) – carbonaceous shale, grey shale, thin coal seams. Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through.
Annual Rainfall	~ 700 mm.
Regolith and Landforms	This HGL is moderately to highly weathered and characterised by a layered stratigraphy of bedded and fractured shale of the Nile Subgroup of the Permian Illawarra Group sediments. These rocks are overlain by a veneer (<4 m) of clay-rich regolith materials. These form localised areas of low hills (<40 m) and rises (9–30 m) and the adjacent alluvial plains. Regolith materials are moderately weathered angular tabular lithic (shaly) pebble-bearing sandy gravels in areas where rock is exposed and highly weathered sandy silts and silty clays forming dispersive, sodic and highly erodible materials in a veneer over low hill and rise landforms. Lithic clayey sands and sandy to silty clays are present on lower colluvial slopes and alluvial plains.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes include Canobla Gap (cgy) on hills and major ridgelines, Glen Alice (gaz) on low hills, rises and mid and lower slopes, and Umbiella (umy) on floodplain. Small basalt outliers on some crests form Mount Tomah (toy) soil landscape. Red Ferrosols (Krasnozems) and Tenosols (Lithosols) are associated with the basalt of Mount Tomah soil landscape. Red and Yellow Kurosols (Red and Yellow Podzolic Soils) and minor Red Dermosols (Terra Rossa Soils) on hillslopes. Brown Kurosols (Solodic Soils) on lower slopes and minor drainage lines. Stratic Rudosols and Tenosols (Alluvial Soils) along the limited floodplain elements.

	Mass movement including minor earth slumps along some basalt derived drainage lines. Mixed colluvial deposits derived from basalt, shale and sandstone on lower slopes. Moderate to severe sheet erosion and gully erosion are present on steeper slopes and along small drainage lines.
Rural Land Capability *(Emery 1986)*	• Class V – sensitive land.
Land Use	Stands of relatively undisturbed sparse native woodland on steeper slopes and grazing on native pastures on lower slopes.
Key Land Degradation Issues	**Limitations**: Severe rill, sheet and gully erosion. Extreme sodicity. Off-site siltation. Dispersive soils. Small saline scalds (<0.5 ha). Seasonal waterlogging (lower slopes/alluvial plains).
Native Vegetation *(Keith 2004; DEC 2006)*	Bourbin Hills HGL supports a uniquely identifiable vegetation assemblage which is suited to the geological unit beneath it, i.e. of the Nile Subgroup within the Illawarra Group sediments. The two local classes of Grassy Woodlands; *Capertee Box – Narrow-Leaf Ironbark –* Callitris *Grassy Woodland*, and *Capertee Rough-Barked Apple – Red Gum – Yellow Box Grassy Woodland* commonly occur on gentle rises such as the eroded hills which make up Bourbin Hills HGL. The eroded hills are generally poorly vegetated. *Capertee Box – Narrow-Leaf Ironbark –* Callitris *Grassy Woodland* is the more common vegetation class of the two, and occurs on rolling to slightly hilly terrain, whereas *Capertee Rough-Barked Apple – Red Gum – Yellow Box Grassy Woodland* is more common in the gullies of the Bourbin Hills. ***See Appendix C for full vegetation descriptions for each Management Area***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Bourbin Hills HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Low to moderate. Range: $<10^{-2}$–10 m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Low. Range: <5%.
Hydraulic Gradient	Moderate. Range: 10–30%.

Groundwater Salinity	Marginal (non NaCl). Range: 0.8–1.6 dS/m.
Depth to Water Table	Deep. Range: >20 m.
Typical Catchment Size	Small (<100 ha).
Scale (Flow Length)	Local. Flow length: <1 km (short).
Recharge Estimate	Moderate.
Residence Time	Medium (years).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Bourbin Hills HGL

Functions this landscape provides within a catchment scale salinity context:

- **H.** The landscape contains high hazard for generating sodic and saline sediment.

Landscape Management Strategies – Bourbin Hills HGL

Appropriate overall strategies pertinent to this landscape:

Buffer the salt store (1): There are minor stores of salt throughout the landscape. The landscape is highly sodic, with moderate – low salinity. Vegetation can mitigate the impacts of salinity and sodicity (high levels of erosion).

Key Management Focus – Bourbin Hills HGL

Focus is management of the sodic, highly erodible landscape and the vegetation management on the landscape. The area is highly eroded and requires soil management programs to be implemented. The use of high rates of mulch has been used successfully on this landscape at Glen Alice. Parts of the area were formerly the Bourbin Hills Soil Conservation Project Area.

Specific Land Management Opportunities

Specific opportunities exist for this HGL:

- Targeting planting of sodic slopes to buffer salt store can impact on salinity.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Do not graze the landscape – too sensitive to erosion.
- This is a difficult and costly landscape to remediate.
- Poor soil conditions that are sodic and highly erodible on slopes.
- Clearing will dramatically increase erosion risk, particularly on slopes areas.
- Pressure for small subdivision.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

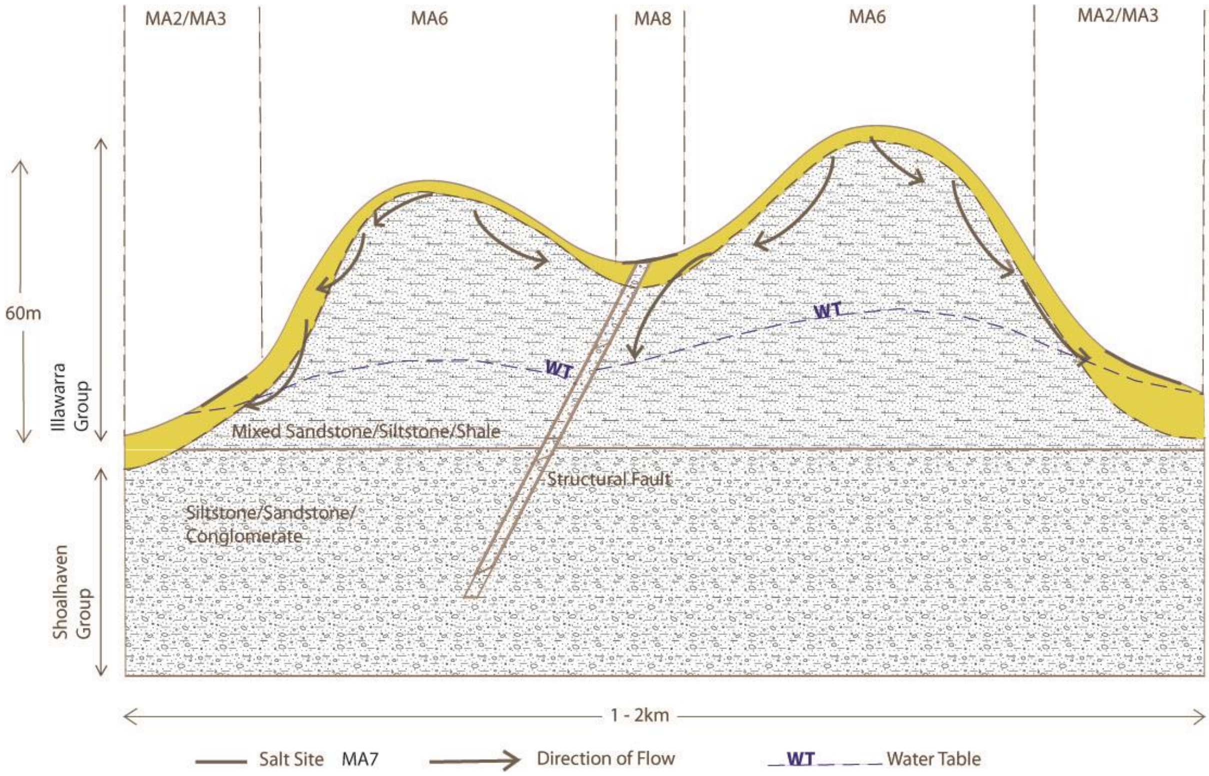


Figure 3: Management cross-section for Bourbin Hills HGL showing defined management areas.

Table 6: Specific management actions for management areas within Bourbin Hills HGL.

Management Area (MA)	Action
MA2 (Upper slopes – erosional) and **MA3** (Upper slopes – colluvial)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Soil ameliorants** Address soil biological health by application of Compost (SA5). **Salt land rehabilitation** Mulching of sites (SR8).
MA6 (Rises)	**Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). **Soil ameliorants** Address soil biological health by application of Compost (SA5). **Salt land rehabilitation** Mulching of sites (SR8).
MA8 (Structural control) and **MA7** (Discharge site – saline)	**Occasional salt site at structures** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). **Small colluvial site** Rehabilitation of salt land to minimise onsite and offsite degradation (SR4). Establish and manage salt land pasture for productive use of salt land (SR2). Mulching of sites (SR8). **Soil ameliorants** Address soil biological health by application of compost (SA5).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Bourbin Hills HGL.

At Risk Management Areas	Action
MA2, MA3, MA6, MA8	Highly sodic landscape is extremely sensitive to poor soils management Area is highly sodic and low- moderately saline (DLU9).
MA2, MA3, MA6	Deep ripping of soils to maximise water infiltration to subsoil (DLU11).
MA7	Flat contour banks and ripping of saline sites will cause considerable degradation (DLU12).
MA2, MA3, MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can significantly increase the erosion risk (DLU4).

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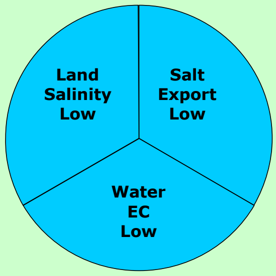
2. Brogan View Hydrogeological Landscape

LOCALITIES	**Cherry Tree**
GEOLOGY SHEET	**Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Brogan View Hydrogeological Landscape (HGL) is located on the margins of the Capertee Valley, on top of the Blue Mountains Plateau in the Mount Vincent area. The area receives >750 mm of rain per annum.

The area is a basalt cap with distinct fertile soils and plateau landform.

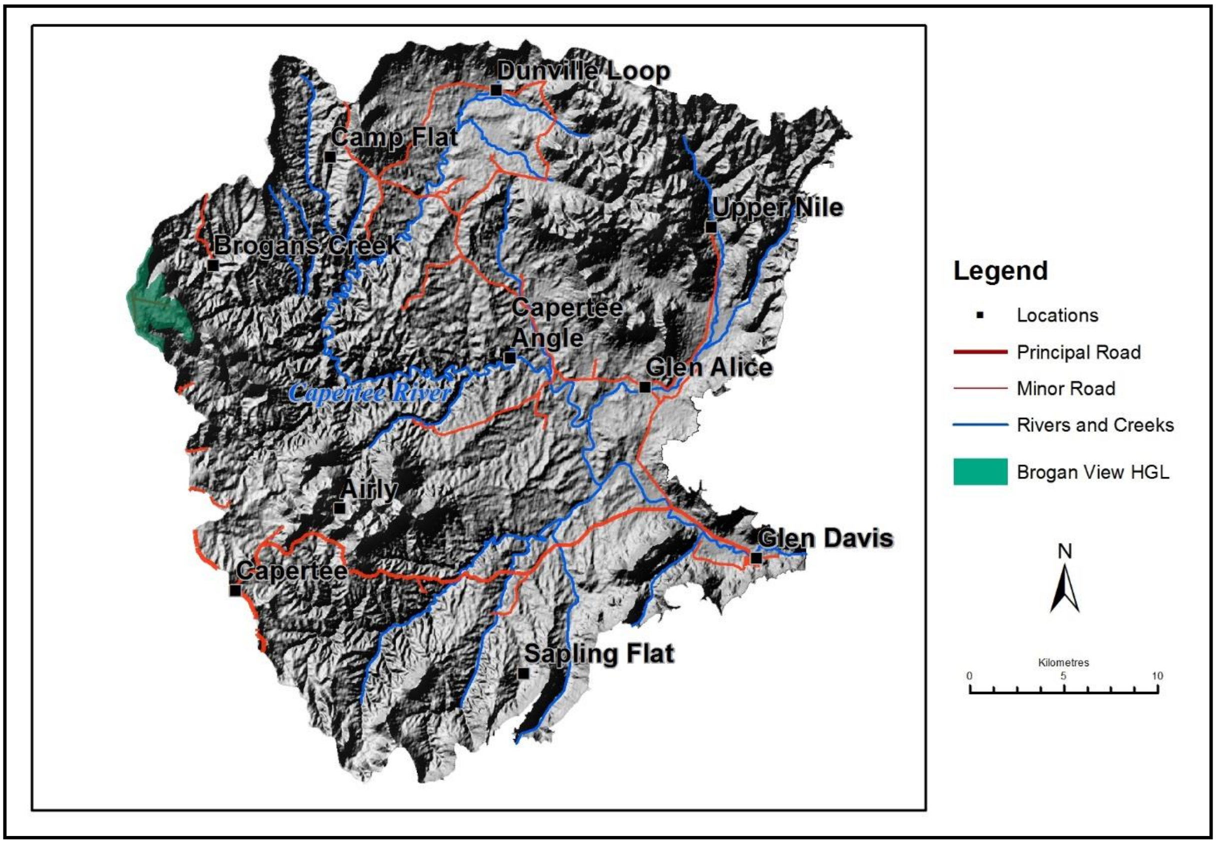


Figure 1: Brogan View HGL location map.

The Brogan View HGL is characterised by deeply weathered relatively small volume basaltic lavas and associated pyroclastic and volcaniclastic sediments. The landscape features an area of rounded low hills and rises with a relatively thick (<90 m) regolith (soil) veneer. This HGL is distinguished because the soils developed on it are fertile and hence support a characteristic vegetation assemblage not observed in other parts of the Capertee Valley area.

The typical lithology for this HGL is Neogene basalt with minor trachybasalt and trachyandesite, forming lava flows with a small volume of associated pyroclastic and volcaniclastic sediments. These lava and volcanic sedimentary materials are almost wholly weathered to clay-rich soils, in the Capertee Valley area. The landscape features a localised area of rounded low hills and rises on top of the Blue Mountains plateau.

Soils are moderately deep to deep, dark reddish brown Krasnozems (pH 5.5–6.5) in well drained areas on upper slopes, and greyish yellow to dull grey Yellow Podzolic Soils and Solodic Soils (pH <6) in less well-drained areas on lower slopes. The soil landscape for this HGL is the Towac Soil Landscape (King 1992).

Water percolates through the relatively well-drained clay-rich soil in upper parts of the landscape but may be retained in less well-drained areas lower in the landscape. Within the landform there may be some control on fluid flow by structures (joints, cooling fractures) in the rock material until water encounters less permeable layers either associated with weathered interflow sediments or the contact with the underlying rock material. This permeability contrast causes water to flow laterally and reach the land surface, sometimes forming freshwater springs. Groundwater quality is typically fresh (EC <0.8 dS/m).

There is extremely limited salt expression on this HGL although there may be very small localised seasonally saline sites associated with evaporative concentration of salts in wetter areas. There is also some less-limited expression of salt here, with a corresponding low salt load to streams and low EC values.

Land use is dominantly grazing on modified pasture and pasture crops, and the landscape has largely been cleared for this purpose. Soil fertility is high and in some areas orchards have developed.

Landscape limitations and hazards include localised sheet and gully erosion in cleared areas.

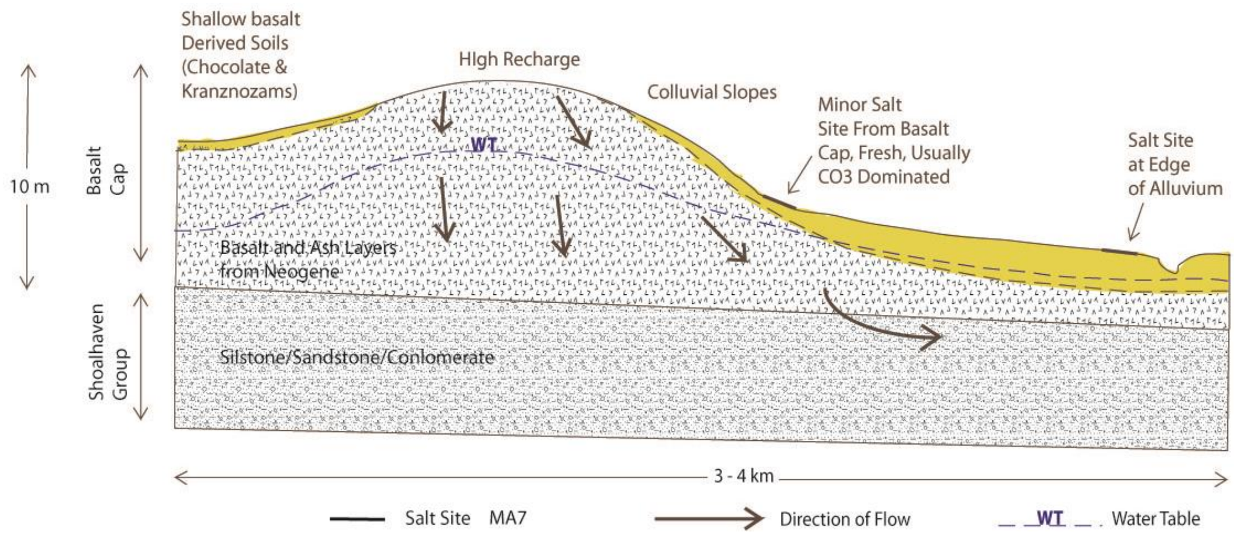


Figure 2: Conceptual cross-section for Brogan View HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Brogan View HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity low. Limited expression of land salinisation on this HGL.
Salt Load (Export)	Salt export low. Although there is potentially a moderate salt store there is limited salt export because (a) the regolith has the capacity to bind cations and hence chemically buffer the salt and (b) the unit sits high in the landscape and is well drained, hence any salt that can be mobilised has been.
EC (Water Quality)	Water EC low. High quality relatively fresh water (<0.8 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Brogan View HGL has low mobility. There is a moderate salt store that has low availability (Table 2).

Table 2: Brogan View HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store	**Brogan View**		
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Brogan View HGL is very low. This is due to the low likelihood of salinity issues and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Brogan View HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Brogan View**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

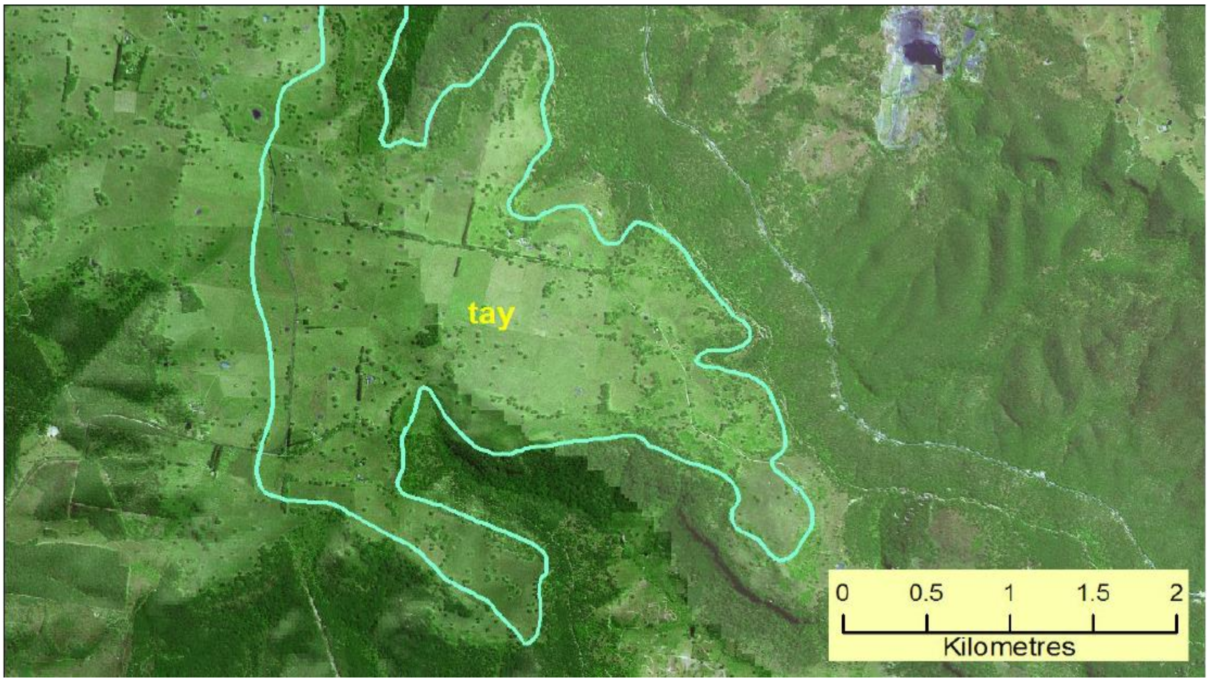


Photo 1: Typical Brogan View – Image sourced from Towac Soil Landscape in Hawkesbury-Nepean DVD Aerial image: DECCW SPOT Image 2005.

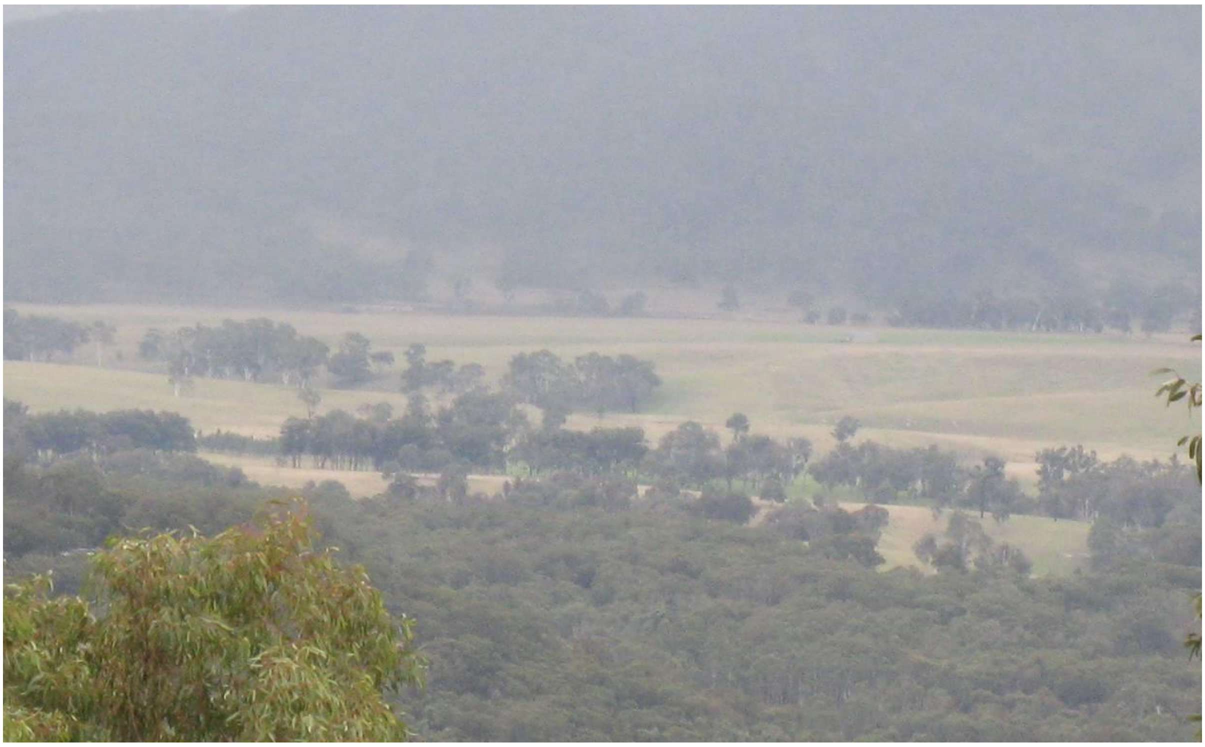


Photo 2: View from Cherry Tree Hill looking north-east, showing cleared basalt rises, of the Brogan View HGL. Photo taken from distance as access to area was restricted (Photo: DECCW/Victoria Cull).

Table 4: Summary of information used to define Brogan View HGL.

Lithology *(Rasmus et al.1969; Geoscience Australia 2016)*	This HGL comprises volcanic rocks (lava flows and associated pyroclastic and volcaniclastic sediments) from the Neogene period. Key lithologies include: • Basalt with minor trachybasalt and trachyandesite.
Annual Rainfall	700–780 mm.
Regolith-Landforms	This HGL is deeply weathered and characterised by a thick clay-rich soil layer over columnar jointed lavas, now stacks of core stones. No rock material is preserved at the land surface. Pyroclastic and volcaniclastic materials are wholly weathered to soils. These form an area of low hills (<40 m) and rises (9–30 m) between 980 m–1080 m ASL, sitting on top of the Blue Mountains plateau. Regolith materials are deeply weathered and are dominantly red brown clays on low hills and rises. Some small iron and manganese nodules are present in the clay subsoils.
Soil Landscapes *(DECC 2008; OEH 2017)*	This HGL consists of the Towac (tay) Soil Landscape in the Mount Vincent area. Moderately deep to deep, dark reddish brown (Ferrosols) Krasnozems (pH 5.5–6.5) are present in well drained areas on upper slopes; and greyish yellow to dull grey Yellow Kurosols and Chromosols (Yellow Podzolic Soils and Solodic Soils) are present in less well drained areas on lower slopes. Little erosion evident.
Rural Land Capability *(Emery 1986)*	• Class IV.
Land Use	Land use is dominantly grazing on modified pasture and pasture crops, and the landscape has largely been cleared for this purpose. Soil fertility is high and some areas have been used for orchards.
Key Land Degradation Issues	**Limitations**: • Localised sheet and gully erosion in cleared areas.
Native Vegetation *(Keith 2004; DEC 2006)*	Most of Brogan View HGL is cleared agricultural land with small patches of the remnant vegetation community interspersed throughout the Mount Vincent area. The patches are unique to areas with basalt influences and are therefore uncommon in the Capertee Valley. The Brogan View HGL (specifically the Mount Vincent area) is a type location for this vegetation community. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Brogan View HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Moderate. Range: 10^{-2}–10 m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Gentle. Range: <10%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Intermediate. Range: 2–8 m.
Typical Catchment Size	Small (<100 ha).
Scale (Flow Length)	Local. Flow length: <5 km (short).
Recharge Estimate	Moderate.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Brogan View HGL

Functions this landscape provides within a catchment scale salinity context:

- **A.** The landscape provides fresh water runoff as an important water source.
- **B.** The landscape provides fresh water runoff as an important dilution flow source.

Landscape Management Strategies – Brogan View HGL

Appropriate overall strategies pertinent to this landscape:

Buffer the salt store (1): There are stores of salt in discrete upper colluvial areas at the contact between the basalt and the underlying geology, which vegetation can buffer, limiting the salinity impact. They are generally in the upper elements of the landscape, and comprise a small percentage of this HGL.

Intercept the lateral flow and shallow groundwater (2): This HGL has discrete shallow water tables that exist at the contact between the basalt and underlying geology. Rows of trees (8–30 rows) can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater.

Discharge rehabilitation (4): The saline sites are generally seasonal (and rare), with low severity. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.

Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Use of groundwater to supplement and replace (7): Groundwater is generally fresh and suitable for use as stock and domestic water supplies. Relatively small changes in groundwater balance can influence on-site and off-site impacts of salinity processes. Surface water can be used to dilute slightly saline groundwater.

Stop discrete landscape recharge (3): High plant water use activities on good soils of the flatter landscape impact on recharge into the basalt capped areas. Perennial pastures and grazing management of natives are strategic actions. The use of trees is an option where rainfall is high.

Key Management Focus – Brogan View HGL

Focus is grazing management on the high rainfall, very fertile soils. Introduced perennials are of high value. Horticulture is conducted in similar areas locally.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- The landscape is very fertile, with black basalt soils. The rainfall is significant, allowing for perennial plantings including horticulture and forestry.
- Discharge management – trees and salt pastures are likely to be very productive in this landscape if correct species are selected, based on salinity tolerance.
- Trees to intercept shallow groundwater will provide exceptional growth as well as providing landscape function.
- Grazing management can affect water balance in this HGL, due to its high catchment response.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- There is a need to balance the management of salinity with water supply. In particular, appropriate revegetation and surface water use.

Specific Targeted Actions

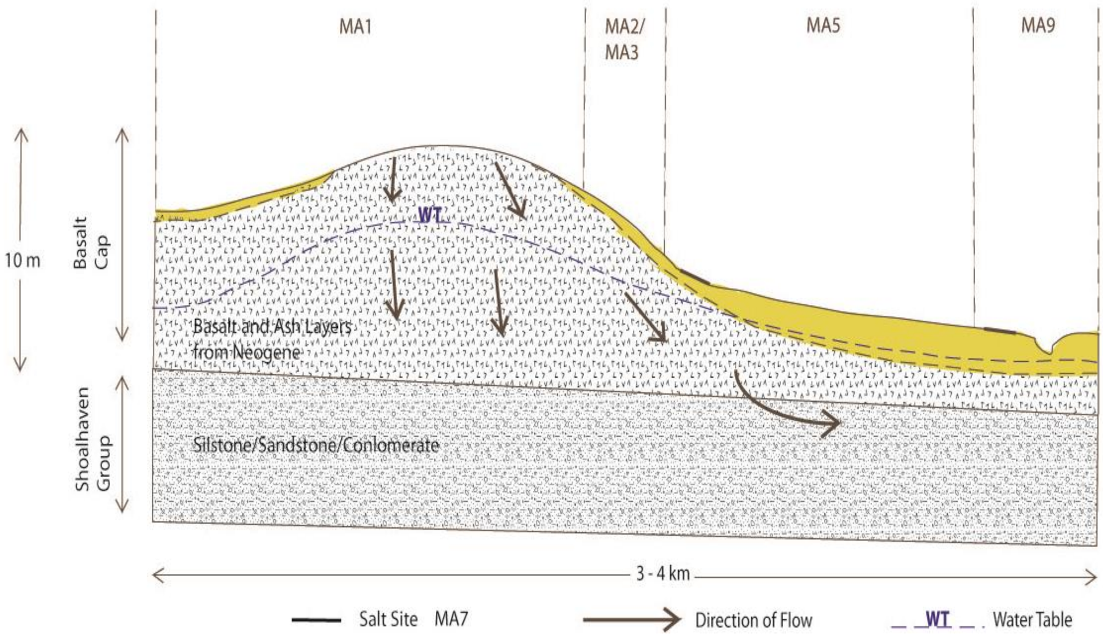


Figure 3: Management cross-section for Brogan View HGL showing defined management areas.

Table 6: Specific management actions for management areas within Brogan View HGL.

Management Area (MA)	Action
MA1 (Ridges) – flat basalt caps	**Vegetation for production** Establishment and management of perennial pastures (VP2). **Vegetation for ecosystem service** Block planting of trees to manage recharge (VE1). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA2 (Upper slopes – erosional)	**Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5).
MA 3 (Upper slopes – colluvial)	**Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5).
MA5 (Lower slopes – colluvial)	**Vegetation for production**

Management Area (MA)	Action
	Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5).
MA7 (Discharge site – saline)	**Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Forestry for productive use of salt land (SR3). Rehabilitation of salt land to minimise onsite and offsite degradation (SR4).
MA9 (Alluvial plain)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Brogan View HGL.

At Risk Management Areas	Action
MA1, MA2, MA3, MA5, MA7	Inefficient grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. System is highly responsive to increase in perennials (DLU2).
MA1, MA2	Annual cropping – has the potential to fill up the soil profile and cause deep drainage. Annual cropping programs do not maximise use of available moisture in this HGL (DLU3).

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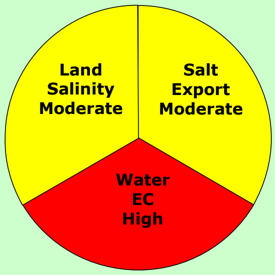
3. Dunns Farm Hydrogeological Landscape (incorporating Snake Hills HGL)

LOCALITIES	**Dunns Farm – Mid Dunville Loop**
GEOLOGY SHEET	**Singleton 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Dunns Farm Hydrogeological Landscape (HGL) is located in the northern part of the Capertee Valley along Dunville Loop. The area receives >800 mm of rain per annum.

This HGL is distinguished from most other HGLs in the Capertee Valley by a 'bench' in the landscape at the base of the cliff section which is vegetated and does not exhibit as severe erosion as in some locations such as Marlyn Gate and Bourbin Hills. This bench in the landscape is sometimes isolated and stands as a low hill with a 'capped' sandstone residual layer on top.

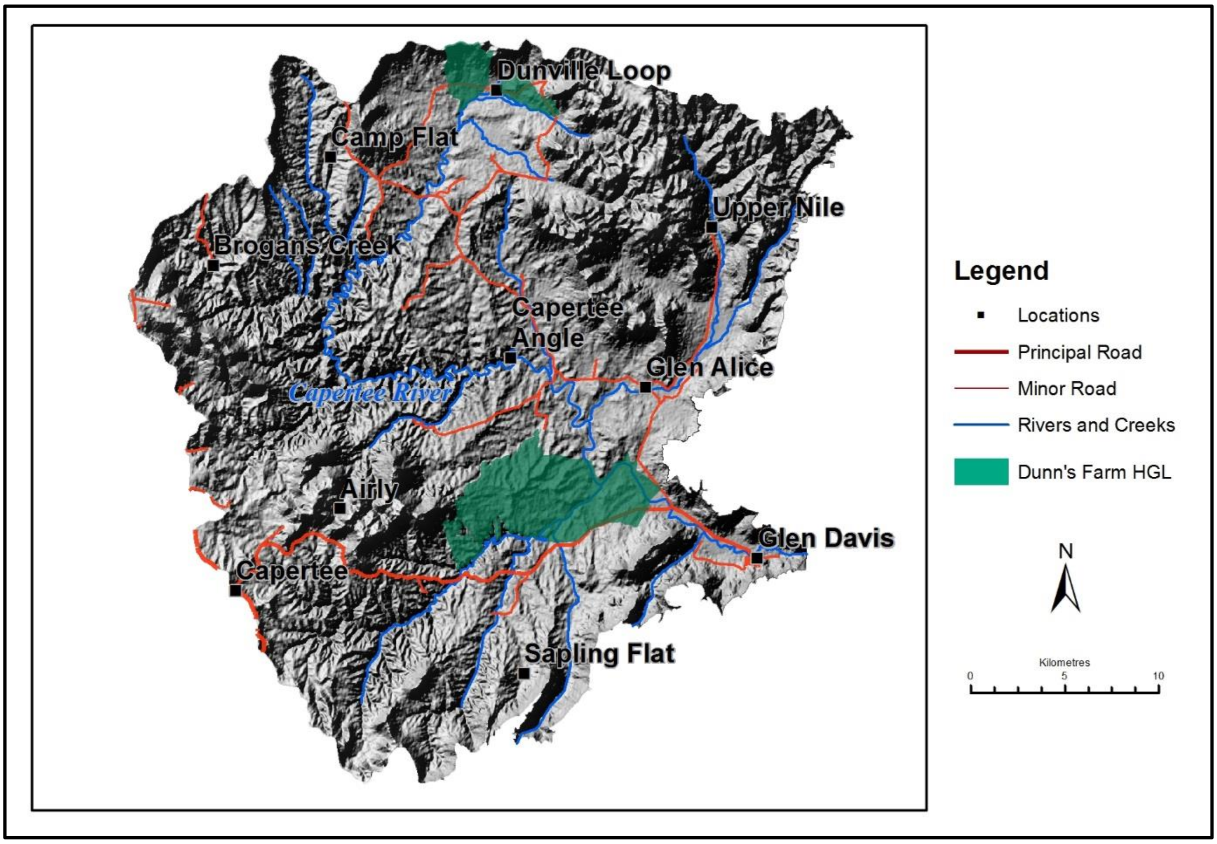


Figure 1: Dunns Farm HGL location map.

The landscape features a steep sandstone escarpment, a talus slope, a prominent 'bench' at the foot of the talus slope surrounded by rises on moderately inclined colluvial slopes.

Typical lithologies for this HGL are sandstone, shale, claystone of the Narrabeen Group, minor coal of the Illawarra Group and siltstone, sandstone and conglomerates of the Shoalhaven Group; which is typical of the flat-lying Permo-Triassic sequence of the catchment.

Water infiltrates through the plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Some of this groundwater will move laterally across bedding in the Illawarra and Shoalhaven Groups, mobilising salts. Water also filters through the unconsolidated rocky sediments forming the talus slope. The lateral movement of subsurface waters may be impeded by a soil texture change (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape water moves laterally through the colluvial materials and may emerge at the land surface in wetter periods.

This landscape features resistant Narrabeen Sandstones, forming a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope. Lower in the landscape areas of hummocky ground, with an associated resistant ‘bench’, opens onto a lower landform of the Glen Alice HGL (broad colluvial slope and alluvial plain).

This HGL has moderate salt sites (<2 ha) that form below the rises at the base of the resistant ‘bench’ on the upper colluvial slopes, where there is a texture contrast and a slope change. Potentially large (<5 ha) seasonal saline scalds may be lower on the colluvial slopes. Because the system has been drier in recent years, this salt expression is less pronounced. There is a notable expression of salt in wet periods and a corresponding low to moderate salt load to streams and moderate EC values. Severe gully erosion has occurred on the upper colluvial slopes in the past and has been managed using earthworks in some cases.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes. Woodland vegetation remains on the cliff and talus slopes.

Landscape limitations and hazards include highly erodible soils and localised sheet and gully erosion, and seasonal saline sites (<5 ha).

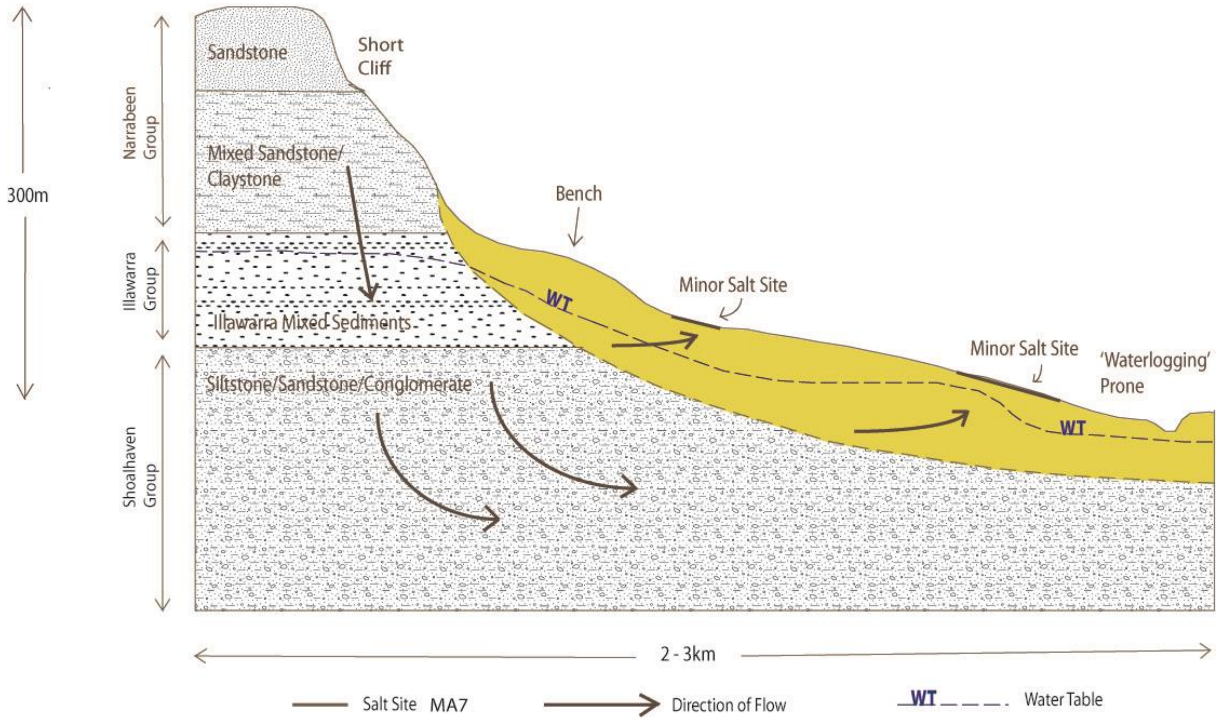


Figure 2: Conceptual cross-section for Dunns Farm HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Dunns Farm HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity moderate. Moderate salt sites (<2 ha) are present immediately below the upper colluvial 'bench' with large seasonal salt sites (<5 ha) lower in the landscape, on the gently inclined colluvial slopes. Sites are more evident in wetter periods.
Salt Load (Export)	Salt export moderate. Moderate flux from saline sites.
EC (Water Quality)	High water EC. In wet times surface water is saline (EC 4–7 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Dunns Farm HGL has high mobility. There is a high salt store that has moderate availability (Table 2).

Table 2: Dunns Farm HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store		**Dunns Farm**	
Moderate salt store			
Low salt store			

Overall salinity hazard is based on the likelihood of salinity and how much impact it will have. The overall salinity hazard in Dunns Farm HGL is moderate. This is due to the moderate likelihood of salinity issues and that they would have potentially significant impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Dunns Farm HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence		**Dunns Farm**	
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Dunville Loop Road looking west, showing colluvial slope grading to undulating valley floor intersected with low hills and rises, of the Dunns Farm HGL (Photo: DECCW/Luke Taylor).

Photo 2: View from Dunville Loop Road looking north-west, showing sandstone/claystone colluvial slope grading into undulating valley floor, of the Dunns Farm HGL (Photo: DECCW/Luke Taylor).

Photo 3: View from Dunville Loop Road looking north, showing sandstone cliffs above colluvial slope and Charbon bench, displaying signs of sheet erosion, of the Dunns Farm HGL (Photo: DECCW/Luke Taylor).

Photo 4: View from Dunville Loop Road near the abandoned quarry looking east, showing undulating rises with salt high in landscape; evidence of erosion on the mid-slope and in lower landscape above drainage depressions, of the Dunns Farm HGL (Photo: DECCW/Victoria Cull).

Photo 5: View from Dunville Loop Road looking north, showing outcropping of rocks from the resistant sandstone layer of Illawarra Group sediments on hill crests, of the Dunns Farm HGL (Photo: DECCW/Luke Taylor).

Table 4: Summary of information used to define Dunns Farm HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: Narrabeen Group – claystone, shale, quartz-lithic sandstone. Illawarra Group (Charbon subgroup) – claystone, siltstone, minor coal. Shoalhaven Group – siltstone, lithic sandstone, conglomerate. The carbonaceous shale and fissile grey shale of the Nile subgroup exhibit yellow discolouration, possibly due to the oxidation of sulphides present within the shales.
Annual Rainfall	>800 mm
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep to precipitous sandstone escarpments, hills (90–200 m) and low hills (30–90 m) in the upper part of the landscape, above steep colluvial talus slopes. There is an elevated 'bench' at the base of the talus slope forming part of the upper colluvial slopes. This 'bench' does not display the erosional surface features observed on similar landscape features in adjacent HGL, suggesting that it is underlain by a different component of the Illawarra Group stratigraphy, most likely the Charbon subgroup. However, earthworks have taken place to address gully erosion in the area in the past decade. The lower colluvial slopes are more gently inclined, with localised rises lower in the landscape. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes.

Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes in descending order of relative elevation are Wollangambe (wox), Mount Sinai (msz) Hassans Walls (hwz), Glen Alice (gaz) and Glen Alice variant a (gaza). Canobla Gap (cgy) occurs on rises on the valley floor. Hassans Walls soil landscape has bare rock faces; where soil has formed it tends to be shallow Rudosols, Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). Bellow the cliff faces talus slopes have formed and soil tends to be moderately deep Yellow and Brown Kurosols (Yellow and Brown Podzolic Soils). The footslopes and drainage lines contain Brown Sodosols (solodic soils) and Brown-Grey Sodosols (Solodized Solonetz). Soil erosion in this landscape does not appear to be as severe as the adjoining Horse gap HGL. Minor to moderate sheet erosion sees the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion is active to partially stabilised.
Rural Land Capability *(Emery 1986)*	• Classes VIII, VII, VI on the vegetated cliff sections. • Class VI on the 'benches' at the base of the talus slope and low hills and rises on the valley floor. • Class V on vegetated lower slopes (minor areas). • Class IV on the colluvial slopes.
Land Use	Native forest remains on hills, with grazing on native and modified pastures lower in the landscape.
Key Land Degradation Issues	**Limitations**: Highly erodible soils (major earthworks in past). Sheet and gully erosion. Wind erosion. Seasonal saline sites (<5 ha). Seasonal waterlogging (lower colluvial/alluvial).
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Dunns Farm HGL is typically of Heathlands and Dry Sclerophyll Forest communities on the highest ridges and plateau areas (MA1) due to the sandstone influence, however there are small patches of Grassy Woodlands on the ridges where sandstone plateaus are capped with residual basalt. The upper erosional slopes (MA2) support both Wet and Dry Sclerophyll Forests which grade into Dry Sclerophyll Forests and Grassy Woodlands, particularly Capertee Box – Narrow-leaf Ironbark – Callitris Grassy Woodland lower down the colluvial slopes (MA3, MA4). Generally, the vegetation in Dunns Farm HGL becomes increasingly dominant in Grassy Woodlands further towards the valley floor (MA5, MA10). ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Dunns Farm HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Low. Range: <10^{-2} m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Low. Range: <5%.
Hydraulic Gradient	Moderate. Range: 10–30%.
Groundwater Salinity	Marginal to saline to high. Range: 0.8–>4.8 dS/m.
Depth to Water Table	Intermediate. Range: 2–5 m.
Typical Catchment Size	Medium (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <5 km (short).
Recharge Estimate	Moderate to high.
Residence Time	Long (decades).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Dunns Farm HGL

Functions this landscape provides within a catchment scale salinity context:

- **D.** The landscape generates salt loads which enter the streams and are redistributed in the catchment.
- **E.** The landscape receives and stores salt load through irrigation or surface flow.

- **F.** The landscape generates high salinity concentration water.

Landscape Management Strategies – Dunns Farm HGL

Appropriate strategies pertinent to this landscape:

Discharge rehabilitation (4): The saline sites are seasonal, with low to moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.

Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Buffer the salt store (1): There are stores of salt in discrete lower colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the lower colluvial elements of the landscape associated with specific stratigraphy and comprise a very small percentage of this HGL where the at-risk geologies do not reach the surface.

Intercept the lateral flow and shallow groundwater (2): This HGL can target shallow water tables that exist at the contact between underlying geology and around rises (benches). Rows of trees (8–30 rows) can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater.

Key Management Focus – Dunns Farm HGL

Focus is primarily on grazing management. There are significant native grass stands across the landscape. Management of the ‘bench’ and capped areas that are sometimes sodic is a localised priority, as is management of salt sites. Earthworks used on salt sites in this area have had favourable outcomes.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Discharge management – trees and salt pastures are likely to be highly productive in the lower landscape element, if correct species are selected based on salinity tolerance. There is abundant shallow groundwater.
- Trees to intercept shallow groundwater will provide salinity control at both upper and lower colluvial salt sites.
- Targeting planting of geological layers to buffer salt store can impact on salinity.
- Opportunity to specifically target the ‘bench’ landforms, to limit recharge to the underlying high risk formations.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Colluvial areas are salty and wet for long periods in winter, which retard plant growth
- Poor soil conditions that are sodic and highly erodible at both salt sites and at ‘bench’ areas.

Specific Targeted Actions

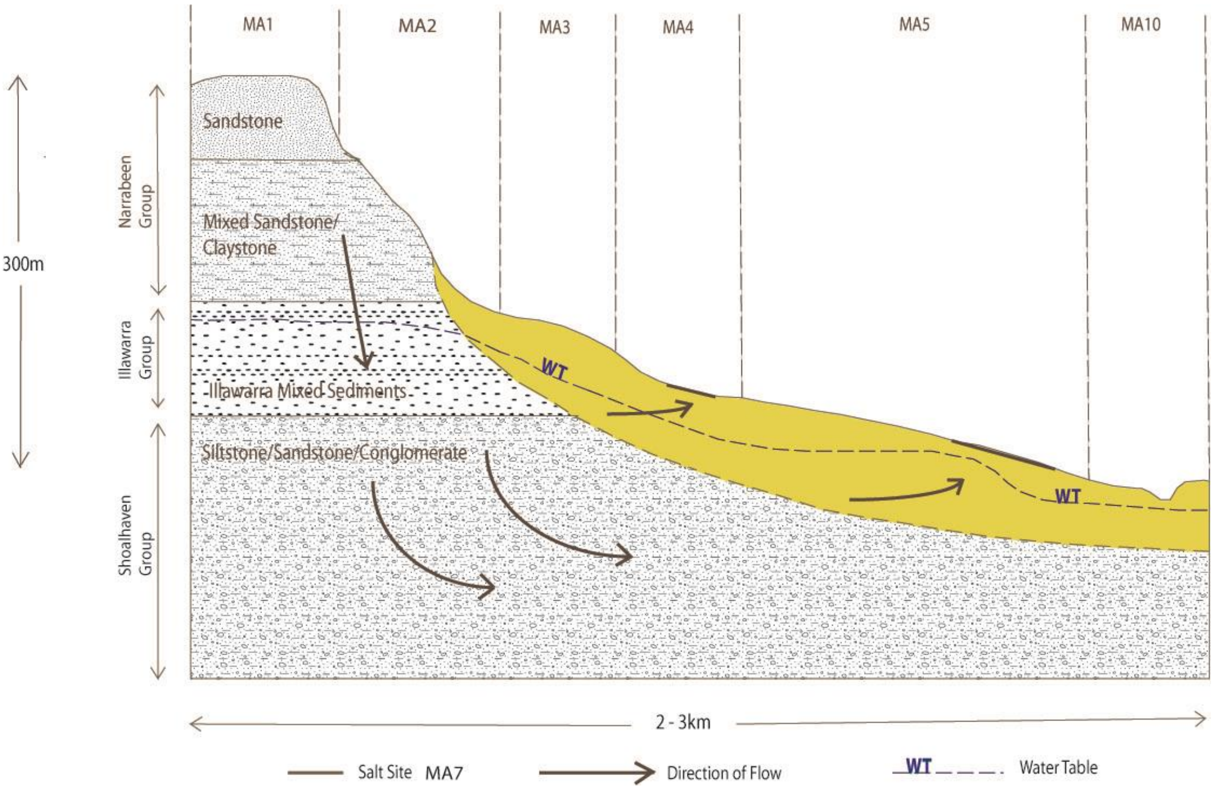


Figure 3: Management cross-section for Dunns Farm HGL showing defined management areas.

Table 6: Specific management actions for management areas within Dunns Farm HGL.

Management Area (MA)	Action
MA1 (Ridges and short cliffs)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) – steep timbered slopes talus slope	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA3 (Upper slopes – colluvial) – geological layer (Charbon Formation)	**Vegetation for ecosystem service** Targeted planting of geological layers to buffer salt store (VE7). Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5).
MA4 (Mid slopes) – short slope under Charbon 'bench'	**Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). Targeted planting of geological layers to buffer salt store (VE7).

Management Area (MA)	Action
	Maintain and improve native woody vegetation (VE3). **Vegetation for production** Interception of shallow lateral groundwater flow with perennial pastures (VP3). Maintain and improve native pastures to manage recharge (VP5). Improve grazing management of existing perennial pastures to manage recharge (VP1). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA5 (Lower slopes – colluvial) – long colluvial slope	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Interception of shallow lateral groundwater flow with perennial pastures (VP3). Maintain and improve native pastures to manage recharge (VP5). Establishment and management of perennial pastures (VP2). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA7 (Discharge site – saline) – minor salt sites on top of colluvium – seasonal salt sites on lower colluvium	**Salt sites on top edge of colluvium** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Vegetation for production** Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Seasonal salt site on lower colluvium** **Vegetation for production** Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). Forestry for productive use of salt land (SR3).

Management Area (MA)	Action
MA 6 (Rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). Targeted planting of geological layers to buffer salt store (VE7).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Dunns Farm HGL.

At Risk Management Areas	Action
MA3, MA4, MA5, MA6, MA7	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA5	Annual cropping – has the potential to fill up the soil profile and cause deep drainage. Annual cropping programs do not maximise use of available moisture in this HGL (DLU3).
MA7	Flat contour banks and ripping of saline sites will cause considerable degradation (DLU12).
MA1, MA2, MA3, MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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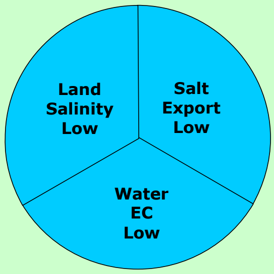
4. Dunville Homestead Hydrogeological Landscape

LOCALITIES	**Dunville Homestead**
GEOLOGY SHEET	**Singleton 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Dunville Homestead Hydrogeological Landscape (HGL) is located on Dunville Loop in the north-eastern section of the Capertee Valley. The area receives >700 mm of rain per annum.

This area is distinguished from other HGLs in that it has very little salinity. The area is high in the stratigraphic sequence in sandstone, shales and claystone sequences that have little salt store.

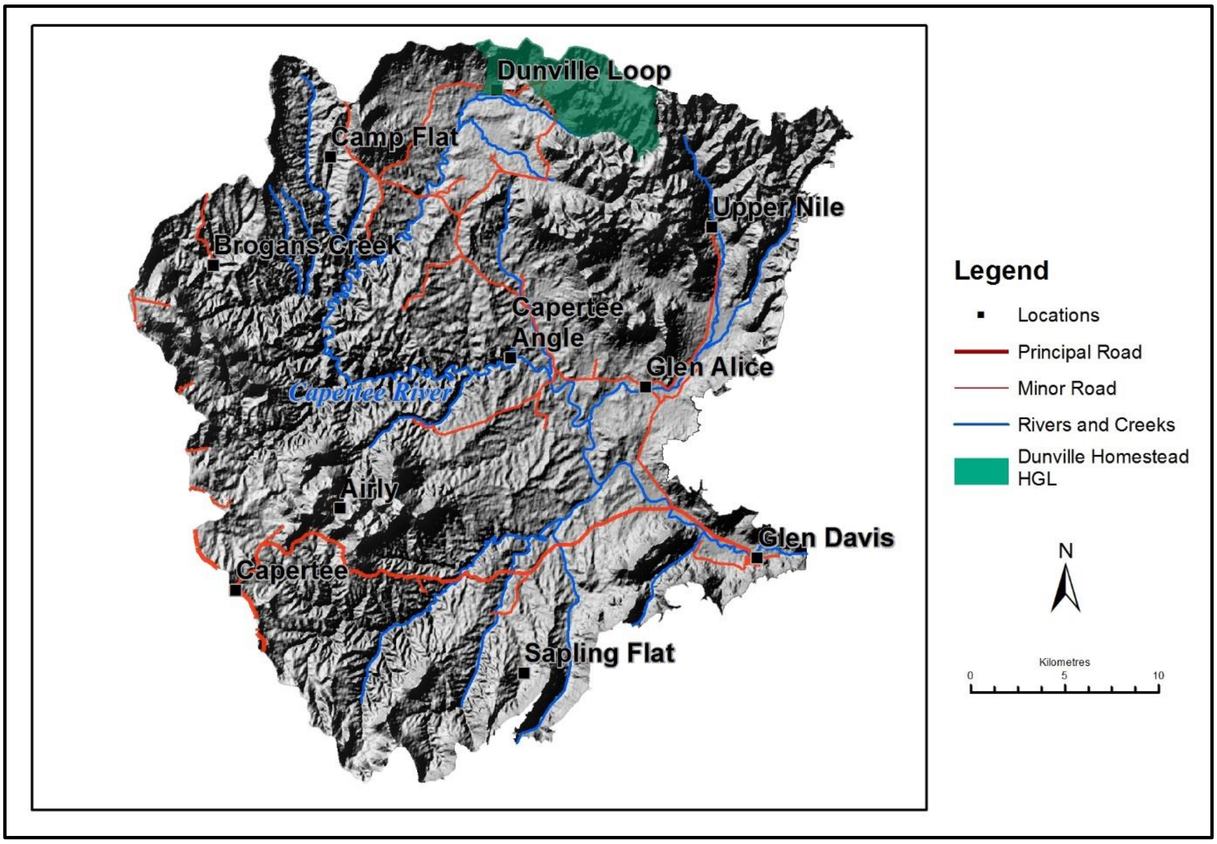


Figure 1: Dunville Homestead HGL location map.

Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and minor coal of the Illawarra Group, and siltstone, sandstone and conglomerates of the Shoalhaven Group, although the lower units are largely obscured by the valley floor sequence. This landscape features resistant

Narrabeen Sandstones, forming a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly talus slope and rolling rises on inclined colluvial midslopes.

Water infiltrates through the plateau surface, high in the landscape, although local surface water catchments are small (<100 ha). The water moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Soil texture change may impede the lateral movement of subsurface waters (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape water moves laterally through the colluvial materials, and may emerge at the land surface in wetter periods. The depth to the water table is intermediate (2–5 m) and the groundwater quality is fresh.

Very little salt is observed in this landscape. Small (<0.5 ha) seasonal saline scalds may be present lower on the colluvial slopes and adjacent to drainage lines, associated with waterlogging. There is limited expression of salt in this HGL and a corresponding low salt load to streams and low EC values.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes and alluvial plains, with localised fodder cropping lower in the landscape. Woodland vegetation remains on the cliff and talus slopes.

Landscape limitations and hazards include: waterlogging and flooding lower in the valley and localised gully erosion and minor sheet erosion.

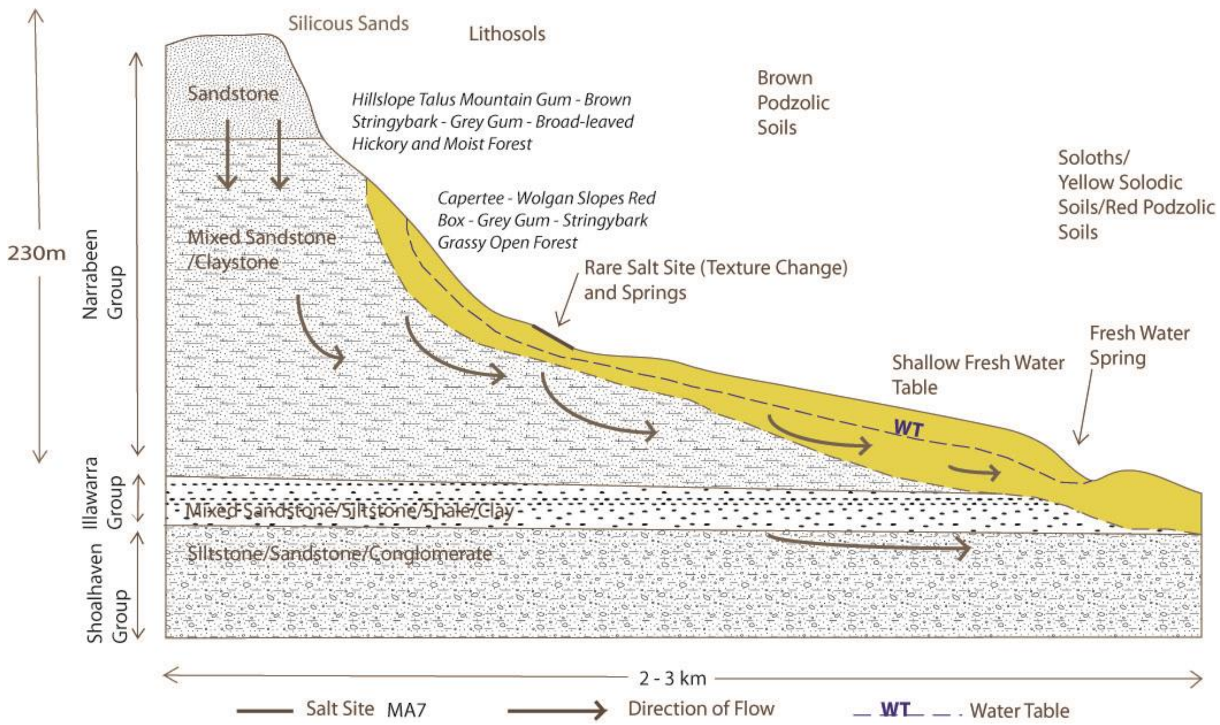


Figure 2: Conceptual cross-section for Dunville Homestead HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Dunville Homestead HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity low. Salt is essentially not observed in this landscape except at very low levels when areas of the lower slopes and alluvial plains are waterlogged.
Salt Load (Export)	Salt export low. Very low levels of salt are exported from the landscape.
EC (Water Quality)	Water EC low. Relatively fresh water (EC 0–0.3 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Dunville Homestead HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Dunville Homestead HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Dunville Homestead**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Dunville Homestead HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Dunville Homestead HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Dunville Homestead**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Dunville Loop Road looking north-west, showing sandstone cliffs and long steep colluvial slope, of the Dunville Homestead HGL (Photo: DECCW/Victoria Cull).

Photo 2: View from Dunville Loop Road looking north-west, showing sandstone cliffs, colluvial slope and broad valley floor with undulating low hills and rises, of the Dunville Homestead HGL (Photo: DECCW/Victoria Cull).

Photo 3: View from Dunville Loop Road looking south-east, showing the broad valley floor which can become waterlogged, of the Dunville Homestead HGL (Photo: DECCW/Victoria Cull).

Table 4: Summary of information used to define Dunville Homestead HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale. Illawarra Group (Charbon subgroup) – claystone, siltstone, minor coal.
Annual Rainfall	~ 700 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Narrabeen and Illawarra Groups, with Shoalhaven Group sediments obscured by the colluvial and alluvial deposits in the bottom of the valley. These form steep sandstone escarpments, hills (90–200 m) and low hills (30–90 m) in the upper part of the landscape, above steep colluvial talus slopes. At the base of the talus slope there is an area of rolling rises (9–30 m) with more gently inclined lower colluvial slopes and localised rises lower in the landscape. The broad alluvial plains of Teatree Creek form the valley floor. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape, and lithic gravelly sands and sandy clays on colluvial slopes. Alluvial channel sediments are siliceous sands and pebble-bearing gravels.
Soil and Landscapes *(DECC 2008; OEH 2017)*	Newnes Plateau (npz) soil landscape occurs on areas of plateau and summit surface. Below this and in descending order of relative elevation lie Wollangambe (wox), Mount Sinai (msz), Greens Creek (gcy), Hassans Walls (hwz), Glen Alice (gaz) and Glen Alice variant a (gaza). Hassans Walls forms a steep relatively short

	sandstone escarpment that separates the plateau from the lower colluvial slopes. The sandstone plateau comprises Newnes Plateau, Wollangambe Mount Sinai and Greens Creek Soil Landscapes. It has widespread Tenosols (Lithosols, Structured Sands, Earthy Sands) and Yellow Kandosols (Yellow Earths). Plateau floor areas have Red and Yellow Kurosols and Chromosols (Red and Yellow Podzolic Soils), Tenosols and Rudosols (Siliceous Sands) and Hydrosols (Prairie Soils). The Valley floor contains Glen Alice (gaz) and Glen Alice variant a (gaza) soil landscapes. Red Kurosols (Red Podzolic Soils) are common. Along drainage lines and in poorly drained lower slope areas typical soils are Brown Sodosols (solodic soils) and Brown-Grey Sodosols (Solodized Solonetz). Moderate to severe sheet erosion sees the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion is active to partially stabilised.
Rural Land Capability *(Emery 1986)*	• Classes VI, VII and VIII on the vegetated hills and upper colluvial slopes. • Class IV on the lower colluvial slopes and valley floor.
Land Use	Native forest remains on hills. Grazing on native and modified pastures is seen lower in the landscape, with some fodder cropping on alluvial plains.
Key Land Degradation Issues	**Limitations**: Waterlogging and flooding (lower colluvial/alluvial). Localised gully erosion and minor sheet erosion.
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Dunville Homestead HGL is typically of Heathlands and Dry Sclerophyll Forest communities on the highest ridges and plateau areas (MA1) due to the sandstone influence. However there are small patches of Grassy Woodlands on the ridges where sandstone plateaus are capped with residual basalt. The upper erosional slopes (MA2) support both Wet and Dry Sclerophyll Forests which grade into Dry Sclerophyll Forests and Grassy Woodlands lower down the slopes. Generally, the vegetation in Dunville Homestead HGL becomes increasingly dominant in Grassy Woodlands further towards the valley floor (MA5). A couple of wetter formations, Forested Wetlands and Freshwater Wetlands, occur along the riverine reaches (MA10) of Brymair Creek in the eastern arm of the HGL. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Dunville Homestead HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Low to moderate. Range: <10^{-2}–10 m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Moderate to steep. Range: 10–>30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Intermediate. Range: 2–5 m.
Typical Catchment Size	Small (<100 ha).
Scale (Flow Length)	Local Flow length: <2 km (short).
Recharge Estimate	Moderate to high.
Residence Time	Medium (years).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Dunville Homestead HGL

Functions this landscape provides within a catchment scale salinity context:

- **A.** The landscape provides fresh water runoff as an important water source.
- **B.** The landscape provides fresh water runoff as an important dilution flow source.
- **C.** The landscape provides important base flow to local streams.

Landscape Management Strategies – Dunville Homestead HGL

Appropriate overall strategies pertinent to this landscape:

Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.

Key Management Focus – Dunville Homestead HGL

The focus is to maintain the vegetation in the landscape to protect the fresh water delivered from the landscape.

Specific Land Management Opportunities

A range of specific opportunities exist for this HGL:

- Fresh water catchment which dilutes the impacts of the salinity contribution of other catchments
- There are significant areas of native pastures and remnant vegetation in this landscape to act as a seed source and basis for sound native pasture and remnant vegetation management
- This HGL has local systems with recharge and discharge commonly on the same farm (short flow paths <4 km).

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Limited constraints mainly due to high level of vegetation in the catchment, and the fact that there is little salt store to come into contact with fresh water.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

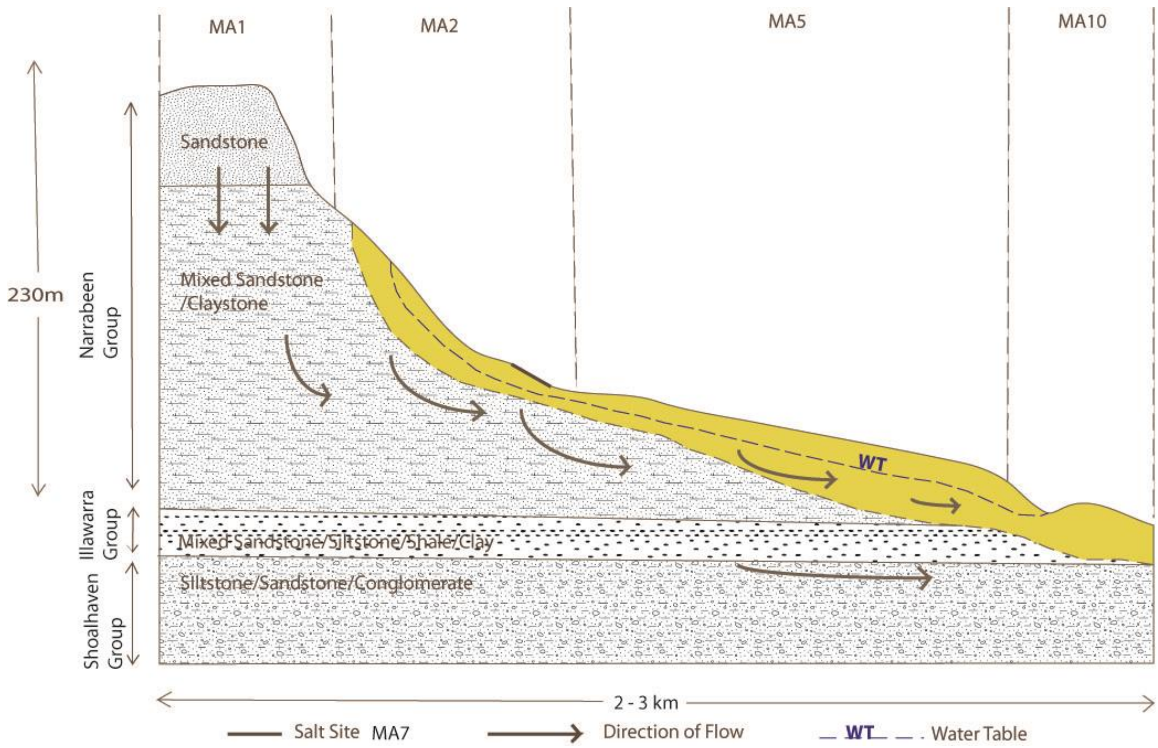


Figure 3: Management cross-section for Dunville Homestead HGL showing defined management areas.

Table 6: Specific management actions for management areas within Dunville Homestead HGL.

Management Area (MA)	Action
MA1 (Ridges)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) - steep timbered slopes	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5).
MA5 (Lower slopes – colluvial) – long colluvial slope	**Vegetation for production** Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA7 (Discharge site – saline) – minor salt sites at texture change	**Minor salt sites at texture change** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Dunville Homestead HGL.

At Risk Management Areas	Action
MA5	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU8).
MA5, MA7	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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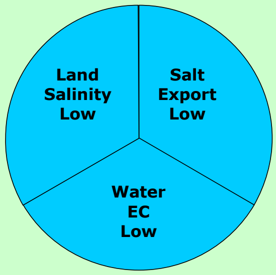
5. Genowlan Mountain Hydrogeological Landscape

LOCALITIES	**Mount Airly and Genowlan Mountain**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Genowlan Mountain Hydrogeological Landscape (HGL) is located in the south-west of the Capertee Valley, and is a distinctive landscape feature (isolated sandstone mountain). The area receives >800 mm of rain per annum.

Genowlan Mountain HGL has similarities with the Mount Marsden HGL. Most of the landscape is heavily vegetated in the upper and midslope areas.

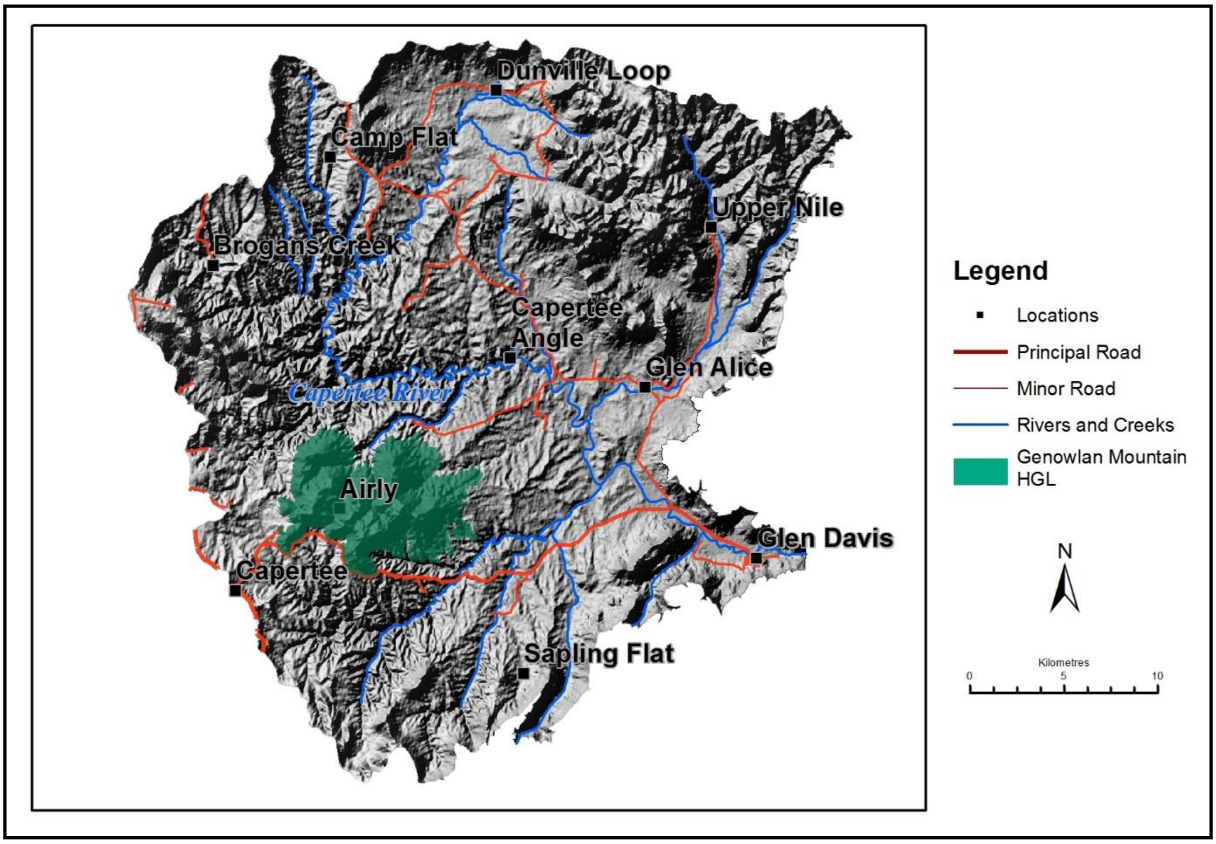


Figure 1: Genowlan Mountain HGL location map.

The Genowlan Mountain HGL is characterised by flat lying Permo-Triassic sandstone, claystone, conglomerate and shale forming a steep-sided elevated plateau. The landscape features a rocky plateau of hills and mountains surrounded by steep sandstone cliffs and talus slopes, with an area of low hills with steep colluvial slopes lower in the landscape, and rises on narrow alluvial plains. This landscape features resistant Narrabeen Sandstones forming a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated talus slope and low hills above short alluvial plain. Weathered Neogene basalt caps some mountain crests forming rolling areas of the landscape, compared to more rocky areas underlain by sandstone.

Water infiltrates through the plateau surface, high in the landscape and the water moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material to recharge the deep water table, unless it encounters less permeable layers in the stratigraphy, causing water to flow laterally. Local surface water catchments are intermediate (100–1000 ha) in size. Water also filters through the unconsolidated rocky sediments forming the talus slope. A soil texture change may impede the lateral movement of subsurface waters (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape water moves laterally through the colluvial and alluvial materials, and may emerge at the land surface in wetter periods. However, typically the depth to the water table is deep (<10 m) in the fractured rock areas and the groundwater quality is fresh (EC <0.8 dS/m).

This HGL has small (<0.5 ha) salt sites that form at the base of some steep colluvial slopes where there is a texture and slope change. This is most notable in poorly drained areas between Mount Airly and Genowlan Mountain underlain by Illawarra Group sediments. Small seasonal saline scalds are lower on the colluvial slopes and adjacent to drainage lines. There is limited expression of salt in this HGL and a corresponding low salt load to streams and low EC values. However, clearing of this landscape may have severe implications for land salinisation and water quality in this area.

Land use is limited to grazing on native pastures in localised areas of cleared land on the plateau and low in the landscape. Native forest remains on the plateau and steep hill slopes. There has been some historical diamond mining on Mount Airly.

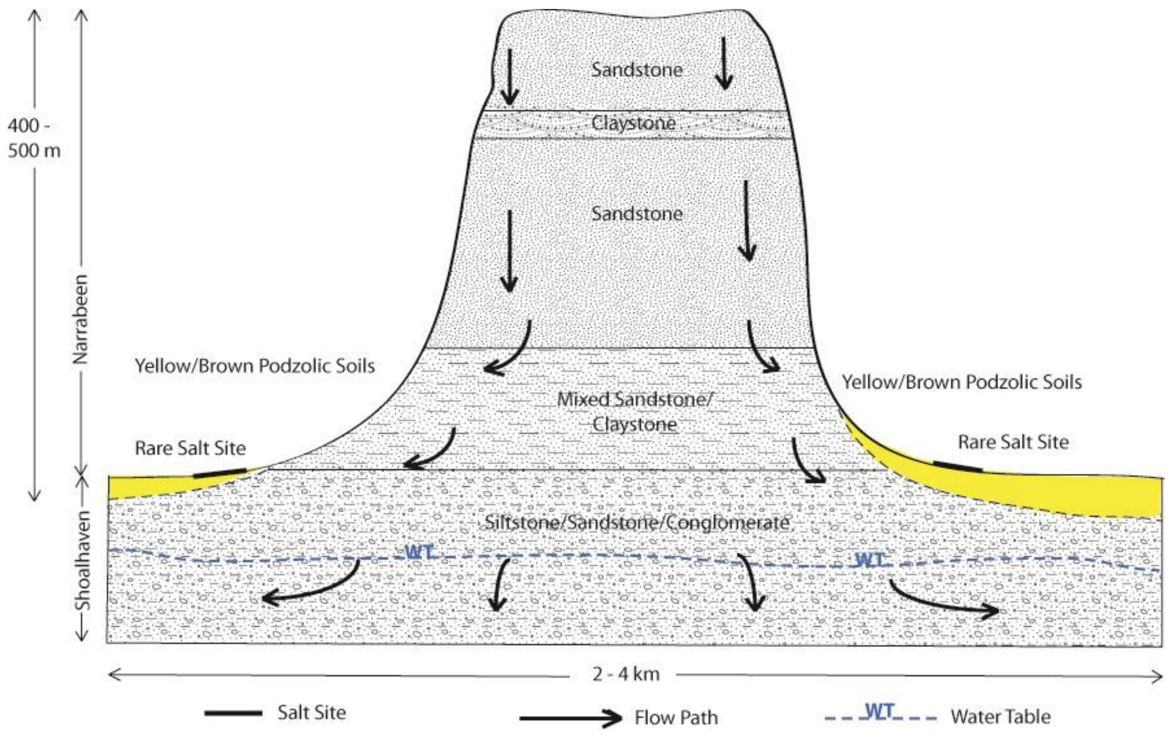


Figure 2: Conceptual cross-section for Genowlan Mountain HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Genowlan Mountain HGL.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity low. Small (<0.5 ha) seasonal salt sites are observed on the cleared lower colluvial slopes, commonly at the change of slope, and on the valley floor adjacent to drainage lines.
Salt Load (Export)	Low levels of salt are exported from the HGL.
EC (Water Quality)	Water EC low. The water quality within the HGL is fresh (EC <0.8 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Genowlan Mountain HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Genowlan Mountain HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Genowlan Mountain**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Genowlan Mountain HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Genowlan Mountain HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Genowlan Mountain**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from the Capertee-Glen Alice Road looking north, showing flat-topped plateau, cliff and steep talus slope on vegetated Narrabeen group and Illawarra group sediments of the Genowlan Mountain HGL (Photo: DECCW/Luke Taylor).

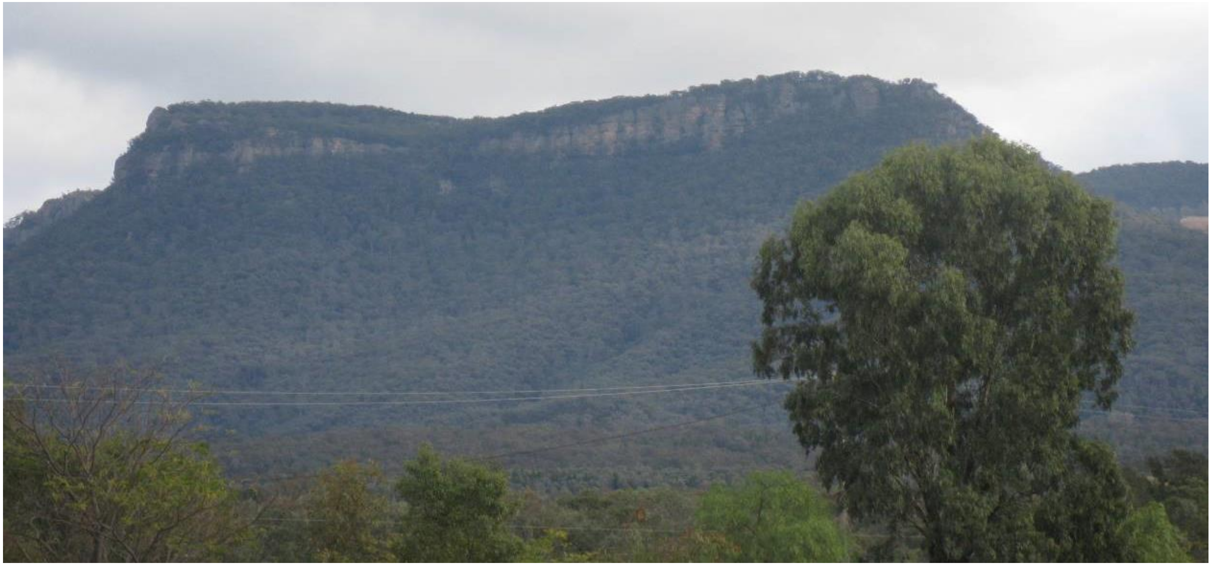


Photo 2: View from the Capertee-Glen Alice Road looking north, showing a close-up of cliff and talus slope, of the Genowlan Mountain HGL (Photo: DECCW/Luke Taylor).

Table 4: Summary of information used to define Genowlan Mountain HGL.

Lithology *(Bryan 1966; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods, with minor remnants of Neogene aged sediments. Key lithologies include: • Unnamed Neogene sediments – sand, silt, clay, gravel • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – claystone, siltstone, minor coal

	• Shoalhaven Group – siltstone, lithic sandstone, conglomerate.
Annual Rainfall	>800 mm.
Regolith and Landforms	This HGL is slightly to moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep to precipitous sandstone mountain escarpments (>300 m), and hills (90–300 m) in the upper part of the landscape forming a large plateau with low hills (30–90 m) and rises (9–30 m) on the flanks of the plateau. Localised areas of moderately weathered Neogene basalt are present on plateau ridge crests. Regolith materials are moderately weathered and dominantly angular tabular lithic and quartz, pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape, and lithic gravelly sands and sandy clays on colluvial slopes.
Soil Landscapes *(DECC 2008; OEH 2017*	Soil landscapes in descending order of relative elevation are Mount Tomah (toy) Medlow Bath (mbz), Wollangambe (wox), Hassans Walls (hwz), Warragamba (wbz), Canobla Gap (cgy) and Cullen Bullen (cbz). Red Ferrosols (Krasnozems) and Tenosols (Lithosols) are associated with the basalt remnants that constitute Mount Tomah soil landscape. This HGL predominantly consists of Permo-Triassic sediments. The crests, ridges and plateau remnants contain Rudosols (Lithosols, Siliceous Sands) and Tenosols (Earthy Sands). On steep slopes, Kandosols (Brown Earths, Yellow Earths), Yellow and Red Kurosols (Yellow and Red Podzolic Soils) and Leptic Rudosols (Lithosols), with Brown and Yellow Kandosols (Brown and Yellow Earths) and Yellow Dermosols (Yellow Podzolic Soils) on less steep sideslopes. The footslopes and drainage lines contain Brown Sodosols (Solodic Soils) and Brown-Grey Sodosols (Solodized Solonetz). Moderate sheet erosion is common on steep hillslopes. Landslip and rock fall are widespread and evident on steep slopes with wet, unstable and disturbed soil. Some tracks have minor sheet and rill erosion (King, 1992).
Rural Land Capability *(Emery 1986)*	• Classes IV and VI on hills, low hills and colluvial slopes on the plateau area and lower colluvial slopes on plateau flanks • Class V on erodible low hills on the plateau (sensitive) • Classes VII and VIII on cliffs and upper colluvial slopes below the escarpment.
Land Use	Native forest remains on plateau and hill slopes. Grazing on native pastures in localised areas of cleared land on the plateau and low in the landscape. Historical diamond mining on Mount Airly.
Key Land Degradation Issues	**Limitations**: • Sheet erosion – cliffs, talus and upper colluvial slopes • Removal of vegetation may allow mobilisation of salt.
Native Vegetation *(Keith 2004)*	The vegetation in Genowlan Mountain HGL is remnant vegetation typical of sandstone ridges and plateau areas (MA1) with basalt influence in the Capertee Valley. The area supports Dry Sclerophyll Forest communities and Heathlands on the plateau

	tops while the erosional and colluvial slopes (MA2/MA3) support both Wet and Dry Sclerophyll Forests which grade into Dry Sclerophyll Forests and Grassy Woodlands lower down the slopes. This HGL contains an Endangered Ecological Community of *Genowlan Point* Allocasuarina nana *heathland* (NSWSC 1998). ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Genowlan Mountain HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Moderate to steep. Range: 10–>30%.
Groundwater Salinity	Fresh to marginal. Range: <0.8–1.6 dS/m.
Depth to Water Table	Deep. Range: >8 m.
Typical Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <5 km (short).
Recharge Estimate	Moderate to high.
Residence Time	Medium (years).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Genowlan Mountain HGL

Functions this landscape provides within a catchment scale salinity context:

- **A.** The landscape provides fresh water runoff as an important water source
- **B.** The landscape provides fresh water runoff as an important dilution flow source.

Landscape Management Strategies – Genowlan Mountain HGL

Appropriate overall strategies pertinent to this landscape:

- **Buffer the salt store (1)**: There are stores of salt in discrete upper colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy, and comprise a very small percentage of this HGL.
- **Discharge rehabilitation (4)**: The saline sites are seasonal, with low to moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6)**: Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Key Management Focus – Genowlan Mountain HGL

The focus is vegetation management to protect the existing remnant vegetation in the landscape. There is a threat of vegetation removal via mining, if mining activity expands.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Targeting planting of geological layers to buffer salt store can impact on salinity, with the rare salt sites that occur in the area.

Lots of existing native vegetation.

The landscape has rare salt sites in the lower colluvium, and the alluvial sites are easily targeted.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Steepness of the slopes, and cliff faces

- Poor soil conditions that are sodic and highly erodible
- Pressure for small subdivision
- Colluvial areas which are salty and wet for long periods in winter, retard plant growth.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

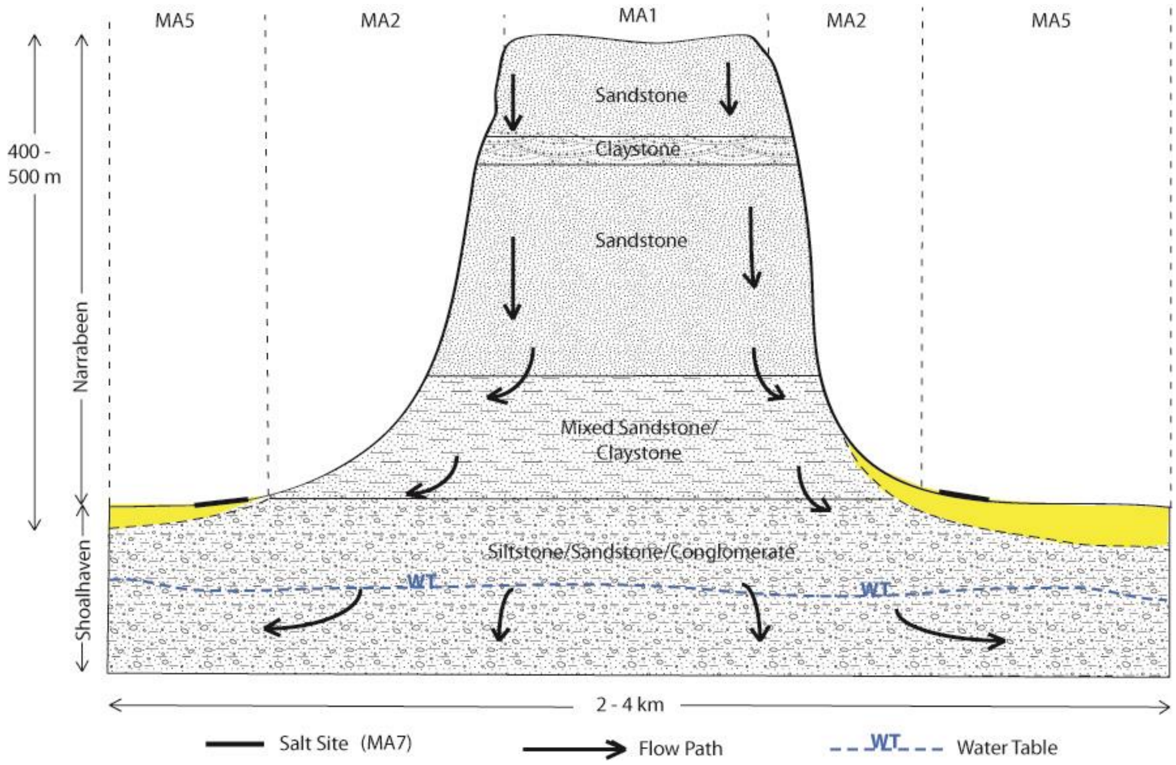


Figure 3: Management cross-section for Genowlan Mountain HGL showing defined management areas.

Table 6: Specific management actions for management areas within Genowlan Mountain HGL.

Management Area (MA)	Action
MA1 (Ridges) Flat-topped escarpment	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) Steep timbered slopes	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA5 (Lower slopes – colluvial)	**Vegetation for ecosystem service** Targeted planting of geological layers to buffer salt store (VE7). Revegetation of non-agricultural land with native species to manage recharge (VE6). Interception planting of trees to target shallow groundwater (VE2). Maintain and improve native woody vegetation (VE3). **Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). Interception of shallow lateral groundwater flow with perennial pastures (VP3). Block planting of perennial edible shrubs to manage recharge (VP6). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA7 (Discharge site – saline) – rare salt site on colluvium – site on edge of alluvial terrace	**Rare salt site on colluvium** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). **Vegetation for ecosystem service** Targeted planting of geological layers to buffer salt store (VE7). Interception planting of trees to target shallow groundwater (VE2). **Seasonal salt site** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). **Alluvial / colluvial site** **Salt land rehabilitation** Rehabilitation of salt land to minimise onsite and offsite degradation (SR4).

Management Area (MA)	Action
	Establish and manage salt land pasture for productive use of salt land (SR2).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Genowlan Mountain HGL.

At Risk Management Areas	Action
MA5	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA5	Annual cropping – has the potential to fill up the soil profile and cause deep drainage. Annual cropping programs do not maximise use of available moisture in this HGL (DLU3).
MA1, MA2, MA5	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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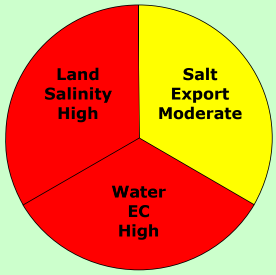
6. Glen Alice Hydrogeological Landscape (incorporating Bourbin Creek and Glencoe HGLs)

LOCALITIES	**Capertee Valley - Dunville Loop, Bogee and Glen Alice**	
GEOLOGY SHEET	**Singleton 1:250 000**	
CONFIDENCE LEVEL	**Low**	

OVERVIEW

The Glen Alice Hydrogeological Landscape (HGL) is located on the valley floors and rises of the Dunville Loop and Glen Alice area. The area receives 625 mm of rain per annum.

This HGL is distinguished from most other HGLs in the Capertee Valley by landscape features of low hills and rises with gently inclined long colluvial slopes and broad alluvial plains. The underlying geology is the Permian Shoalhaven Group including the Berry Formation and the Megalong Conglomerate.

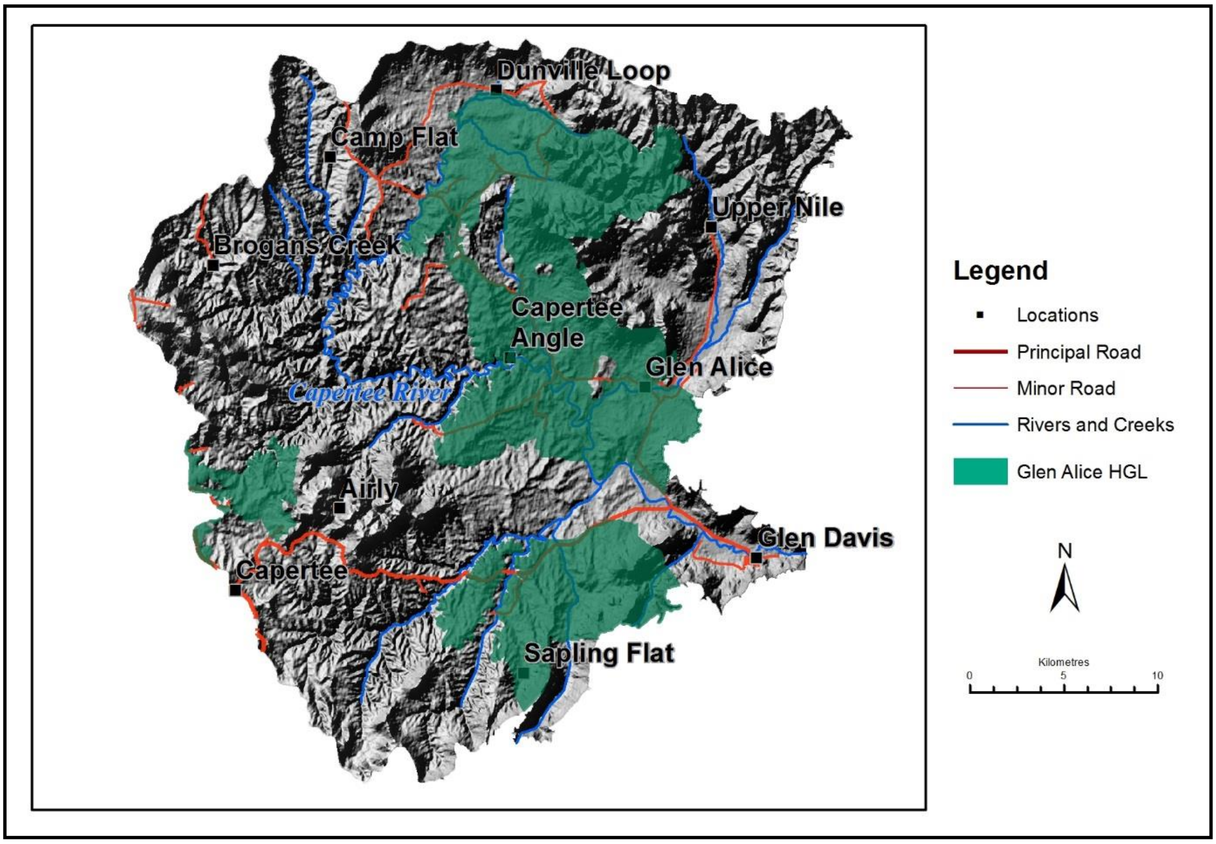


Figure 1: Glen Alice HGL location map.

Typical lithologies for this HGL are sandstone, conglomerate and siltstone of the Permian Shoalhaven Group. These rocks dominate this HGL forming an open rise and plain landscape. This landscape features rolling rises (9–30 m) with gently inclined colluvial slopes and broad alluvial plains, developed on the Shoalhaven Group sediments.

Water moves laterally through the unconsolidated colluvial and alluvial sediments and emerges at the land surface in wetter periods. The lateral movement of subsurface waters is impeded by a soil texture change (lithic gravels and sands to sandy clay) at the change in slope. Local surface water catchments are intermediate (100–1000 ha) in size. The depth to the water table is shallow to intermediate (2–8 m) and the groundwater quality is marginal to brackish (EC 0.8–4.8 dS/m).

Large salt sites (5–10 ha) are found on the broad plains and floodplains of the valley floor. The sites are persistent but display seasonal variation. Smaller salt sites (0.5–2 ha) also occur on the mid and lower slopes at changes in slope and along drainage lines. The lower lying parts of this HGL are subject to waterlogging and flooding, and salt sites in this part of the landscape reflect these seasonal changes. Some are associated with ponding behind structural barriers (e.g. resistant beds). Soils are generally sodic and occasionally strongly saline.

The land use in this area is grazing on native and modified pastures, with some areas of fodder cropping on colluvial slopes and alluvial plains.

Landscape limitations and hazards include sheet erosion on upper colluvial slopes, some gully erosion on lower colluvial slopes and along drainage lines, and seasonal waterlogging and flooding on alluvial plains. Severe land salinisation is expressed on valley flats and is more pronounced in wetter periods.

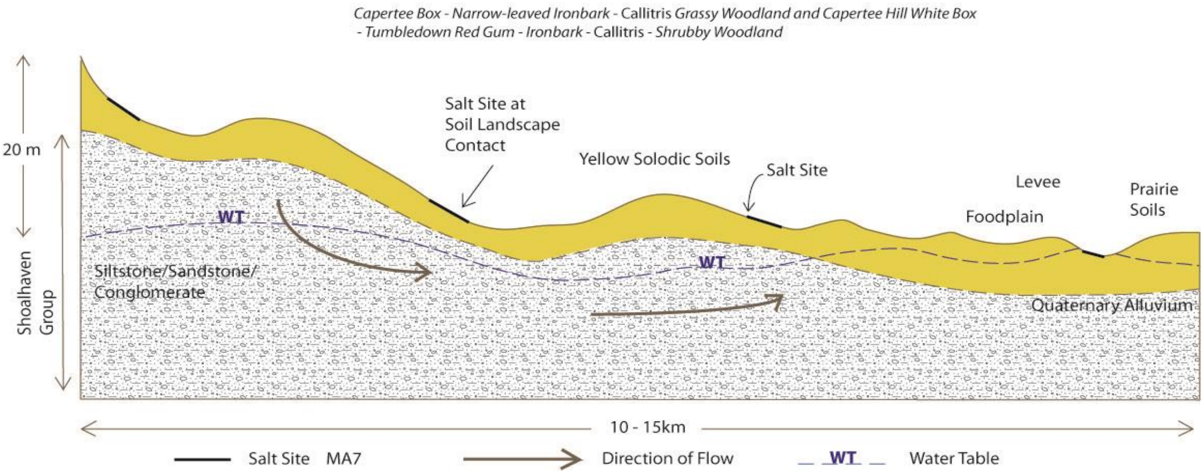


Figure 2: Conceptual cross-section for Glen Alice HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Glen Alice HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity is high. Seasonal salt sites are observed on the broad colluvial slopes and the valley floor. Sites along the floodplains of creeks can be quite large (5–10 ha). Irrigation in this landscape increases the expression of land salinisation. A significant amount of salt is stored within the colluvial and alluvial sediments of the valley floor. Multiple small sites are associated with changes in slope on rolling rises and along drainage lines, with localised large sites behind structural barriers, and sites on alluvial plains influenced by seasonal waterlogging.
Salt Load (Export)	Moderate levels of salt are exported from the HGL.
EC (Water Quality)	Water EC high. The water quality within the HGL is marginal to brackish (EC 0.8–4.8 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Glen Alice HGL has high mobility. There is a high salt store that has moderate availability (Table 2).

Table 2: Glen Alice HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store		**Glen Alice**	
Moderate salt store			
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Glen Alice HGL is very high. This is due to the high likelihood that salinity issues will occur and that they would have potentially severe impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Glen Alice HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			**Glen Alice**
Moderate likelihood of occurrence			
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from the Port Macquarie Road looking west, showing low rolling hills with occasional Kurrajongs, on the Glen Alice HGL (Photo: DECCW/Luke Taylor).

Photo 2: View from Tambo Road looking north-west, showing rolling rises and plains of the valley floor, of the Glen Alice HGL (Photo: DECCW/Victoria Cull).

Photo 3: View from the Port Macquarie Road looking west, showing low rolling hills in the foreground of the Glen Alice HGL (Photo: DECCW/Luke Taylor).

Photo 4: View from the Glen Alice Road looking south-east, showing flat floodplain with deep alluvial soils of the Glen Alice HGL (Photo: DECCW/Fletcher Townsend).

Photo 5: View from Dunville Loop Road looking south-east towards Glen Davis, showing extensive floodplains with rolling rises of the valley floor (Photo: DECCW/Victoria Cull).

Photo 6: View from Tambo Road looking west, showing salt scald along the floodplain of Capertee River of the Glen Alice HGL (Photo: DECCW/Victoria Cull).

Photo 7: View from Glen Alice Road facing north-west, showing the constricted drainage line of Bourbin Creek where large sodium bicarbonate salt sites occur. The hills and low rises in the background form part of the south-west constriction boundary, of the Glen Alice HGL (Photo: DECCW/Luke Taylor).

Table 4: Summary of information used to define Glen Alice HGL.

Lithology *(Rasmus et al.1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian period. The key lithology is: • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through.
Annual Rainfall	~ 625 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, siltstone and conglomerate of the Shoalhaven Group sediments, largely obscured by the colluvial and alluvial deposits in the bottom of the valley. This HGL forms an area of rolling rises (9–30 m) with gently inclined colluvial slopes. A broad alluvial plain (0–9 m) forms the valley floor. Regolith materials are moderately weathered and dominantly lithic gravelly sands and sandy clays on rises and colluvial slopes. The alluvial plains preserve gravelly sands and sandy clays to organic sandy clays.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes include Canobla Gap (cgy) on hills and major ridgelines, Dunville (dun) and Glen Alice (gaz) on low hills, rises and mid and lower slopes, Rowans Hole (roz) on rises and Umbiella (umy) on floodplain. Most of this HGL comprises Yellow and Red Kurosols (Yellow and Red Podzolic Soils). Brown Kurosols (Solodic Soils) occur in drainage depressions with limited Red Dermosols (Terra Rossa Soils) on mid and lower slopes and Stratic Rudosols and Tenosols (Alluvial Soils) on floodplain elements. Moderate to severe sheet erosion with the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion which is active to partially stabilised.

Rural Land Capability *(Emery 1986)*	• Class IV on rises and colluvial slopes • Class V on eroded and salinised land (sensitive)
Land Use	Grazing on native and modified pastures with some areas of fodder cropping on colluvial slopes and alluvial plains.
Key Land Degradation Issues	**Limitations**: • Saline sites • Moderate sheet erosion • Some gully erosion.
Native Vegetation *(Keith 2004)*	Glen Alice HGL exhibits open-woodland communities which are partially to extensively cleared. Rises (MA6) and lower colluvial slopes (MA5) support Dry Sclerophyll Forests and Grassy Woodlands containing *Callitris* sp. and kurrajongs which indicate soil variation. Remnant paddock trees representing the original Dry Sclerophyll Forest and Grassy Woodland communties are commonly kurrajongs, indicating salinity outbreak sites as they are a saline tolerant species. There are three discrete portions of the Glen Alice HGL with slightly different vegetation signatures. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Glen Alice HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Moderate. Range: 10^{-2}–10 m/day.
Aquifer Transmissivity	Low to moderate. Range: <2–100 m^2/day.
Specific Yield	Low to moderate. Range: <5–15%.
Hydraulic Gradient	Gentle. Range: <10%.
Groundwater Salinity	Marginal to brackish. Range: 0.8–4.8 dS/m.
Depth to Water Table	Intermediate. Range: 2–8 m.
Typical Catchment Size	Intermediate (100–1000 ha).
Scale	Local.

(Flow Length)	Flow length: <10km (short to intermediate).
Recharge Estimate	Moderate.
Residence Time	Medium to long (years to decades).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Glen Alice HGL

Functions this landscape provides within a catchment scale salinity context:

- **E.** The landscape receives and stores salt load through irrigation or surface flow
- **D.** The landscape generates salt loads which enter the streams and are redistributed in the catchment
- **F.** The landscape generates high salinity concentration water.

Landscape Management Strategies – Glen Alice HGL

Appropriate overall strategies pertinent to this landscape:

Intercept the lateral flow and shallow groundwater (2): Target shallow water tables at slope change. Rows of trees (8–30 rows) can be effective to intercept lateral flow. Rooting depth will intercept shallow groundwater.

Discharge rehabilitation (4): The saline sites are low-moderate and highly seasonal, with moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.

Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Key Management Focus – Glen Alice HGL

Focus is primarily on grazing management. There are significant native grass stands across the landscape. Management of eroded sections that are usually sodic is a localised priority, as is management of salt sites where they occur.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Good soils that are well drained
- Salt sites occur high in the landscape at slope changes adjacent to minor gullies that can be readily targeted
- Slopes contribute fresh water that dilutes impacts of other catchment's salinity contribution
- There are significant areas of native pastures and remnant vegetation in this landscape to act as a seed source and basis for sound native pasture and remnant vegetation management
- This HGL has local systems with recharge and discharge commonly on the same farm (short flow paths <4km).

Specific Land Management Constraints

Constraints for land management in this HGL include:

- The flat alluvial plain area is moderately to highly sensitive
- Ripping of the area is likely to significantly increase erosion and increase recharge which will mobilise salt to the adjacent stream
- Pressure for annual cropping
- Species selection will require waterlogging tolerance as well as salinity tolerance
- Species selection will need to match site conditions.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

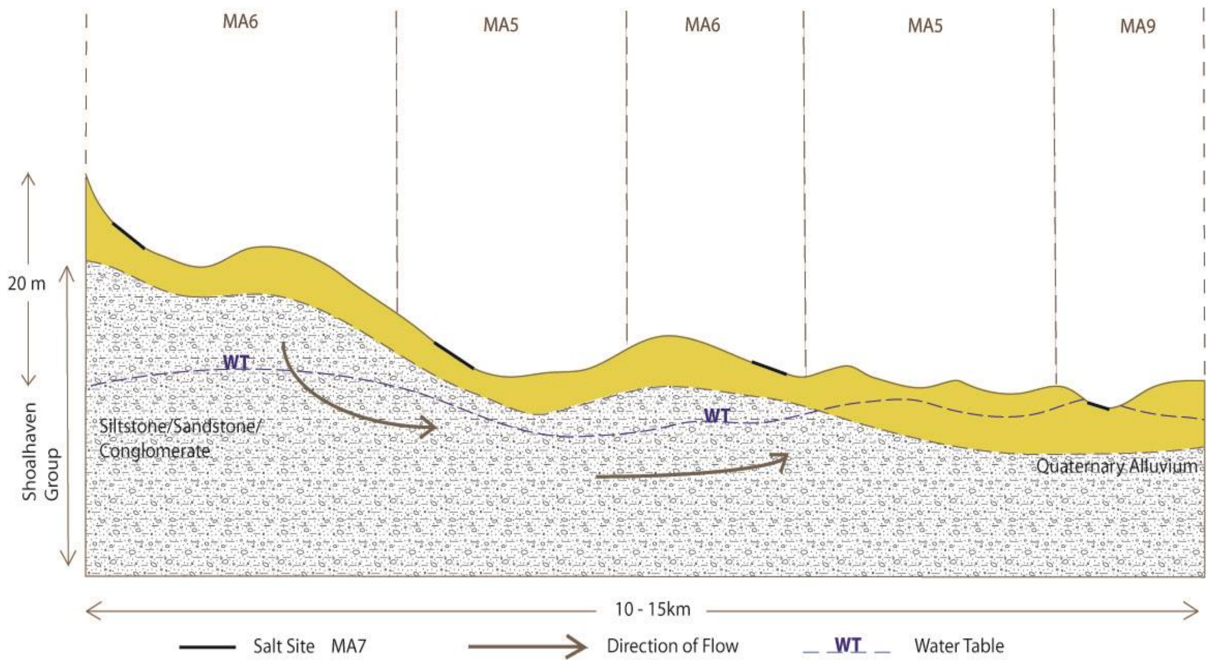


Figure 3: Management cross-section for Glen Alice HGL showing defined management areas.

Table 6: Specific management actions for management areas within Glen Alice HGL.

MANAGEMENT AREA (MA)	ACTION
MA6 (Rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA5 (Lower slopes – colluvial)	**Vegetation for production** Maintain and improve native pastures to manage recharge (VP5). Improve grazing management of existing perennial pastures to manage recharge (VP1). Interception of shallow lateral groundwater flow with perennial pastures (VP3). Establishment and management of perennial pastures (VP2). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Interception planting of trees to target shallow groundwater (VE2). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). Forestry for productive use of salt land (SR3).
MA9 (Alluvial plain)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). Establishment and management of perennial pastures (VP2). Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).

MANAGEMENT AREA (MA)	ACTION
	Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). Forestry for productive use of salt land (SR3). Establish and manage salt tolerant edible shrubs for productive use of salt land (SR5).
MA7 (Discharge site – saline) – colluvial salt sites at slope change	**Colluvial salt sites at slope change** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). Forestry for productive use of salt land (SR3). Establish and manage salt tolerant edible shrubs for productive use of salt land (SR5). Rehabilitation of salt land to minimise onsite and offsite degradation (SR4). **Vegetation for production** Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Glen Alice HGL.

At Risk Management Areas	ACTION
MA5, MA6, MA9	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).
MA7	Flat contour banks and ripping of saline sites will cause considerable degradation (DLU12).
MA9 (Alluvial plain)	Deep ripping of the flat alluvial soils will initiate erosion in the highly sodic subsoils, as well as increase the local recharge (DLU11).

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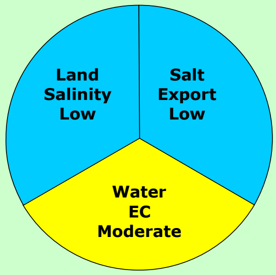
7. Glen Davis Hydrogeological Landscape

LOCALITIES	**Glen Davis**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Glen Davis Hydrogeological Landscape (HGL) is located in the Capertee Valley at Glen Davis settlement and the surrounding landscape. The area receives >600 mm of rain per annum.

The landscape is dominated by large sheer cliffs and a small alluvial plain on the edge of the Capertee River.

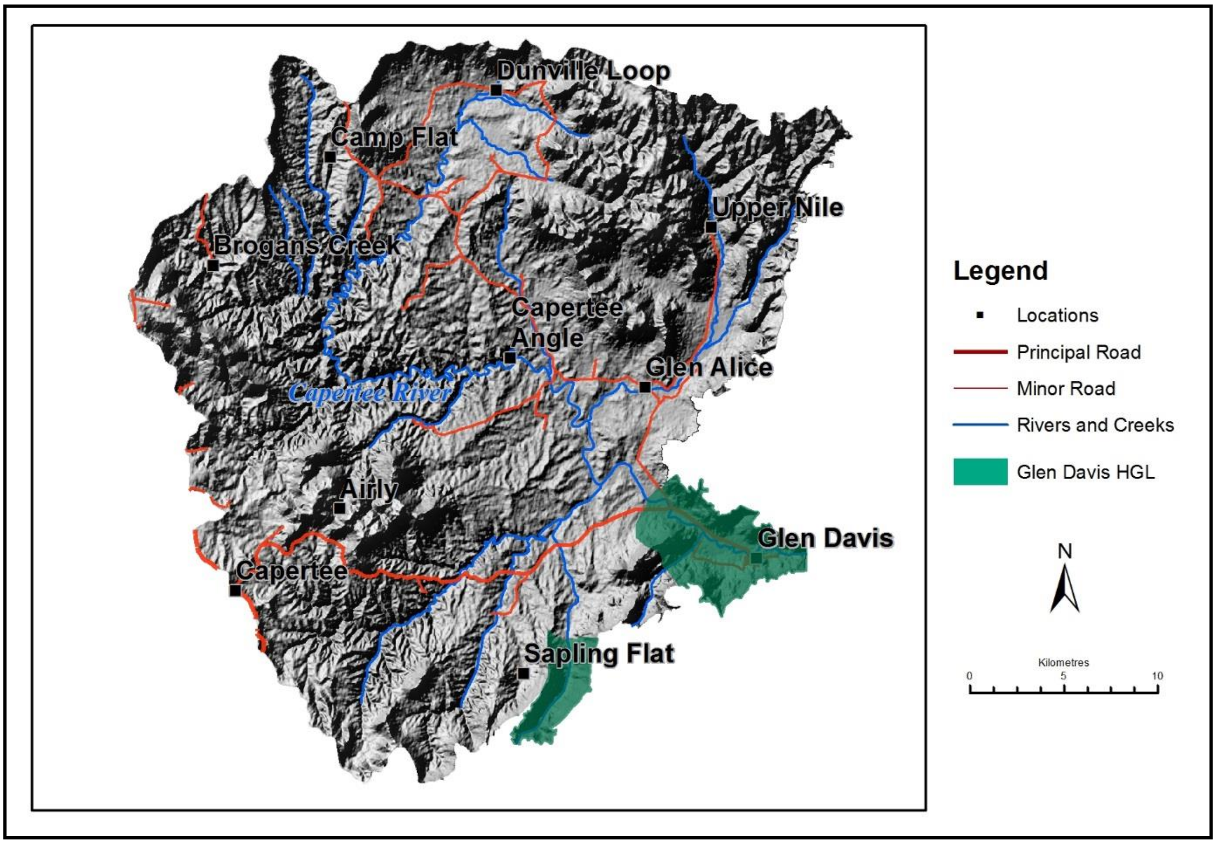


Figure 1: Glen Davis HGL location map.

Glen Davis HGL is characterised by flat lying Permo-Triassic sandstone, claystone, conglomerate and shales. The landscape features a steep sandstone escarpment, a short talus slope and minor colluvium, with an alluvial plain adjacent to the Capertee River. Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and minor coal of the Illawarra Group, and siltstone, sandstone and conglomerates of the Shoalhaven Group, although the lower units are largely obscured by the valley floor sequence. This landscape features resistant Narrabeen Sandstones, forming a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly talus slope and minor colluvium and alluvium of the Capertee River.

Water infiltrates through the plateau surface, high in the landscape, and the water moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Local surface water catchments are small to intermediate (100–1000 ha). The lateral movement of subsurface waters may be impeded by a soil texture change (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape water moves laterally through the colluvial and alluvial materials, and may emerge at the land surface in wetter periods. The depth to the water table is intermediate (2–5 m) and the groundwater quality is fresh.

Very little salt is observed in this landscape. Small (<0.5 ha) seasonal saline scalds may be present lower on the alluvial plains and adjacent to drainage lines, associated with waterlogging. There is limited expression of salt in this HGL and a corresponding low salt load to streams and low EC values. In the subsurface there is potential for more saline layers in the stratigraphy (Nile Subgroup of the Illawarra Group) to contribute salt to aquifers.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes and alluvial plains, with localised fodder cropping lower in the landscape. Woodland vegetation remains on the cliff and talus slopes. The Glen Davis landscape has a medium response time to changes in land management.

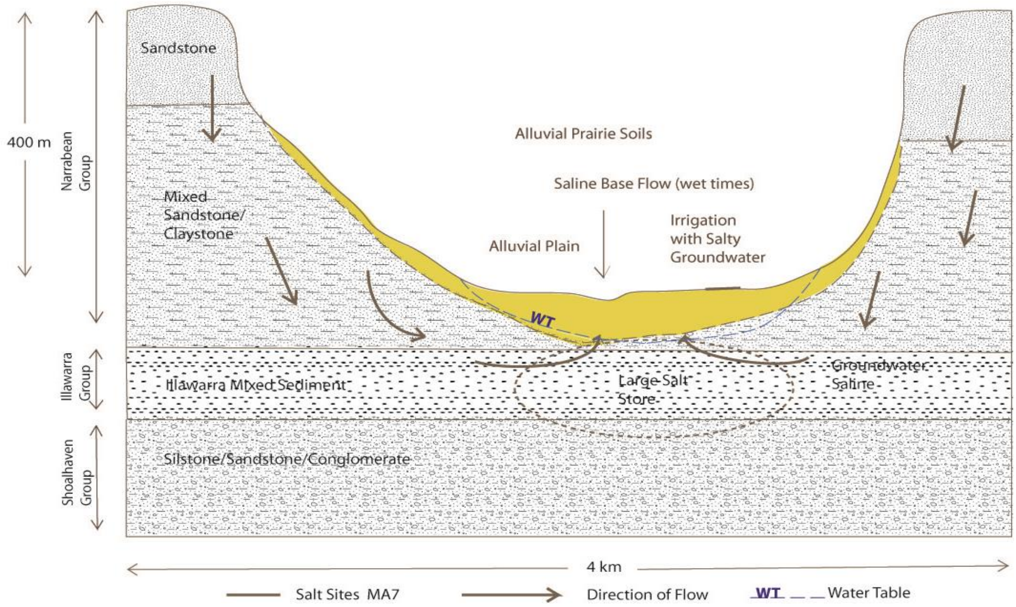


Figure 2: Conceptual Glen Davis HGL cross-section showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Glen Davis HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity low. Limited salt is observed along main drainage lines in wet periods, probably associated with a contribution from saline base flow.
Salt Load (Export)	Salt export low. Low amounts of salt are exported from the land surface. Salts may be exported under the land surface, through regional groundwater systems.
EC (Water Quality)	Water EC is moderate. Salty aquifers contribute to marginal to brackish base flow. In wet times, runoff and fresh water flows from upstream dilute the flow.

In Table 2 salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Glen Davis HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Glen Davis HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Glen Davis**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Glen Davis HGL is low. This is due to the low likelihood that salinity issues will occur and that they would have potentially moderate impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Glen Davis HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence	**Glen Davis**		
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Glen Davis-Capertee Road looking east towards Glen Davis, showing sandstone cliffs and plateaus either side of valley floor and Capertee River Floodplain, of the Glen Davis HGL (Photo: DECCW/Victoria Cull).

Photo 2: View from Glen Davis Road looking east towards Glen Davis, showing sandstone cliff, colluvial slope, valley floor with undulating rises, as shown in foreground, of the Glen Davis HGL (Photo: DECCW/Victoria Cull).

Photo 3: View from Glen Davis Road looking east towards Glen Davis, showing broad valley floor at base of colluvial slope, of the Glen Davis HGL (Photo: DECCW/Victoria Cull).

Table 4: Summary of information used to define Glen Davis HGL.

Lithology *(Bryan 1966; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – claystone, siltstone, minor coal. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of the Capertee River, which passes through this HGL.
Annual Rainfall	~ 600 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Narrabeen and Illawarra Groups, with Shoalhaven Group sediments obscured by the colluvial and alluvial deposits in the bottom of the valley. These form steep sandstone escarpments, hills (90–200 m) and low hills (30–90 m) in the upper part of the landscape, above steep colluvial talus slopes. At the base of the talus slope there is an area of rolling rises (9–30 m) with more gently inclined lower colluvial slopes. The broad (>100 m) alluvial plains of the Capertee River form the valley floor. Physiographically, the Glen Davis area of the Capertee Valley is surrounded to the north-east, south-east and south-west by the Blue Mountains plateau. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels

	and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes. The alluvial plains preserve gravelly sands and sandy clays to organic sandy clays.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes in descending order of relative elevation are Wollangambe (wox), Canobla Gap (cgy), Hassans Walls (hwz), Mount Sinai (msz), Rowans Hole (roz) Glen Alice (gaz) and Umbiella (umy). This HGL predominantly consists of Permo-Triassic sediments. The crests, ridges and plateau remnants contain Rudosols (Lithosols, Siliceous Sands) and Tenosols (Earthy Sands). On steep slopes, Kandosols (Brown Earths, Yellow Earths), Yellow and Red Kurosols (Yellow and Red Podzolic Soils) and Leptic Rudosols (Lithosols), with Brown and Yellow Kandosols (Brown and Yellow Earths) and Yellow Dermosols (Yellow Podzolic Soils) on less steep sideslopes. The footslopes and drainage lines contain Brown Sodosols (Solodic Soils) and Brown-Grey Sodosols (Solodized Solonetz). Moderate sheet erosion is common on steep hillslopes. Landslip and rock fall are widespread and evident on steep slopes with wet, unstable and disturbed soil. Some tracks have minor sheet and rill erosion (King, 1992).
Rural Land Capability *(Emery 1986)*	• Classes VI, VII and VIII on upper slopes. • Classes IV and V on mid and lower slopes and valley floors.
Land Use	Native forest remains on hills. Grazing on native and modified pastures lower in the landscape, and fodder cropping on alluvial plains. The rural settlement of Glen Davis occurs within the HGL.
Key Land Degradation Issues	**Limitations**: • Widespread sheet erosion hazard • Localised gully erosion hazard • Stream bank erosion along Capertee River • Localised flood hazard • Localised waterlogging.
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Glen Davis HGL is characteristic of the narrow, protected valleys that exist between high sandstone plateaus or rounded crests, their colluvial sideslopes grading into rolling rises and a broad valley floor in the east of the Capertee Valley. Vegetation supported by these valley landforms is consistent across other eastern Capertee valleys such as near Glen Alice, and hence the Glen Davis HGL exhibits similar vegetation to the Nile HGL. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Glen Davis HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Low to moderate. Range: <10^{-2}–10 m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Moderate to steep. Range: 10–>30%.
Groundwater Salinity	Fresh to marginal. Range: <0.8–1.6 dS/m.
Depth to Water Table	Intermediate. Range: 2–5 m.
Typical Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <5 km (short).
Recharge Estimate	Moderate to high.
Residence Time	Medium to long (years to decades).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Glen Davis HGL

Functions this landscape provides within a catchment scale salinity context:

- **E.** The landscape receives and stores salt load through irrigation or surface flow.

Landscape Management Strategies – Glen Davis HGL

Appropriate overall strategies pertinent to this landscape:

Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.

Key Management Focus – Glen Davis HGL

The focus is on management of the short colluvium with grazing management, and the alluvial plain with soil, irrigation and vegetation management. There is a salt store in the alluvium that needs to be 'static' and not mobilised by excess infiltration.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- The landscape is non-saline
- Soils are alluvial, and fertile
- There are significant areas of native pastures and remnant vegetation left in this landscape for biodiversity purposes
- Runoff from the hill-slopes act as dilution flows.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- The landscape has highly saline groundwater
- Salt stores exist in the deeper alluvium.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

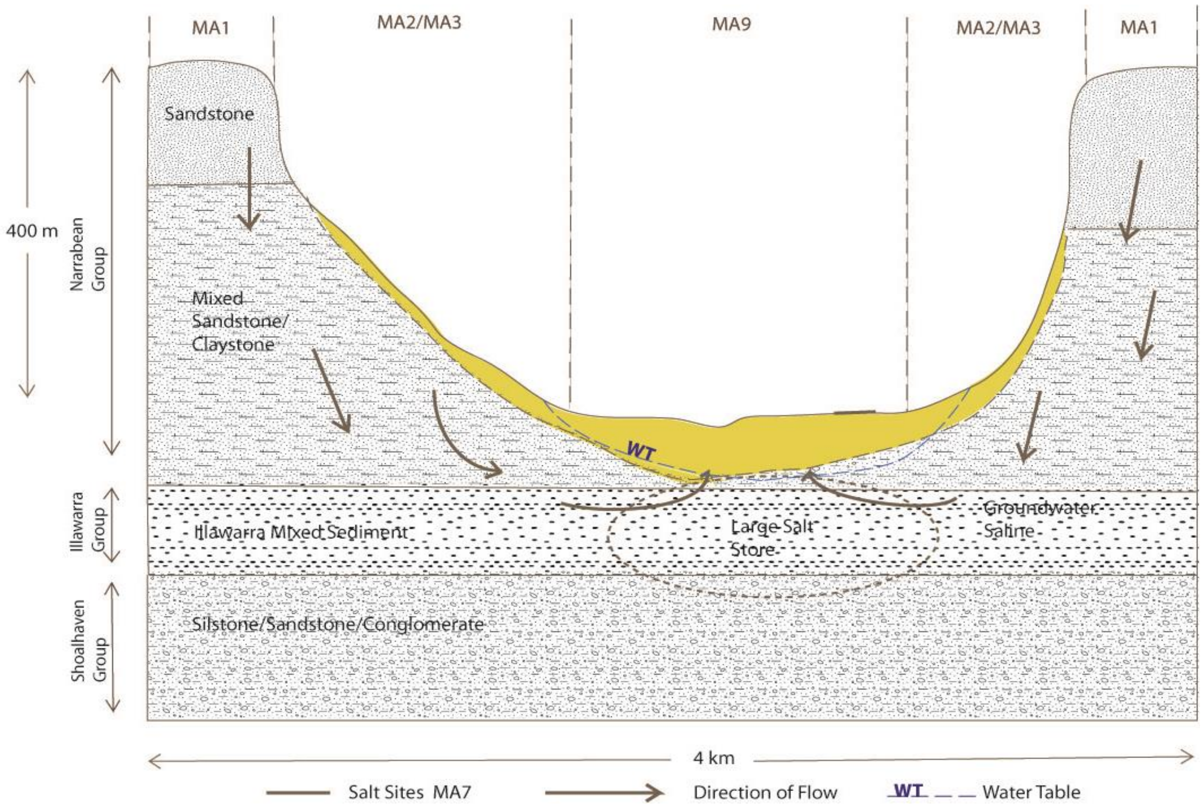


Figure 3: Management cross-section for Glen Davis HGL showing defined management areas.

Table 6: Specific management actions for management areas within Glen Davis HGL.

Management Area (MA)	Action
MA1 (Cliffs)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) and **MA3** (Upper slopes – colluvial) – steep timbered slopes	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA9 (Alluvial plain) – salt store deep in alluvium – saline groundwater	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). Establishment and management of perennial pastures (VP2). **Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Glen Davis HGL.

At Risk Management Areas	Action
MA9 (Alluvial Plain)	Deep ripping of the flat alluvial soils will increase the local recharge (DLU11).
MA9 (Alluvial Plain)	Poor soils management will increase accessions to the water table (DLU9).
MA3, MA9	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2, MA3	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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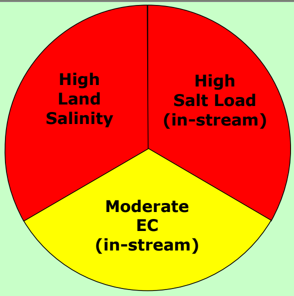
8. Horse Gap Hydrogeological Landscape

LOCALITIES	**Horse Gap**
MAP SHEET	**Singleton 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Horse Gap Hydrogeological Landscape (HGL) is located in the northern area of Capertee Valley along Dunns Loop. The area receives >800 mm of rain per annum.

The area is unique as it is characterised by a constricted bowl-shaped valley on flat-lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale within the Capertee Valley at Horse Gap which is extremely saline in the lower landform.

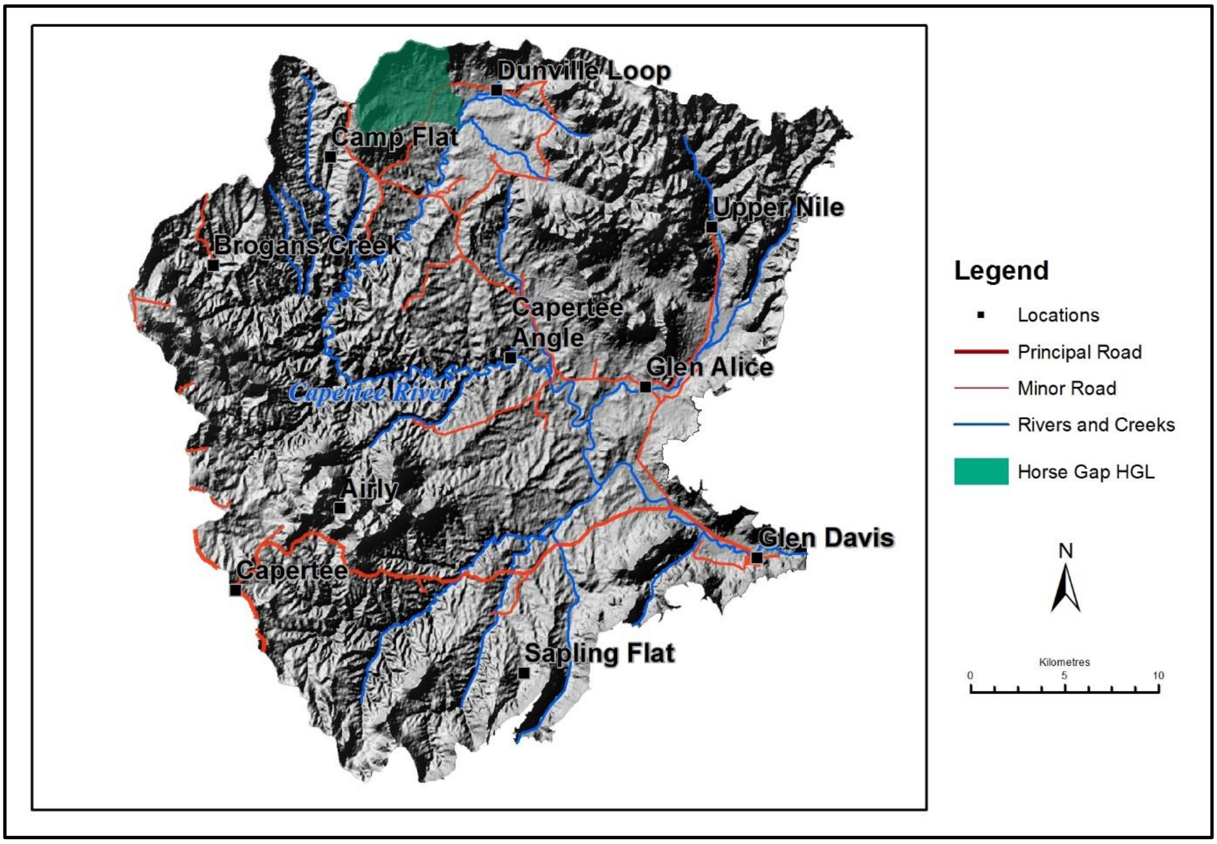


Figure 1: Horse Gap HGL distribution map.

Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and minor coal of the Illawarra Group, and siltstone, sandstone and conglomerates of the Shoalhaven Group.

Water infiltrates through the plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Low in the section, some of this groundwater will move laterally across bedding in the Illawarra and Shoalhaven Groups, mobilising salts. Water also filters through the unconsolidated rocky sediments forming the talus slope. The lateral movement of subsurface waters may be impeded by a soil texture change (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape, water moves laterally through the colluvial materials, and may emerge at the land surface in wetter periods. The constricted bowl shape of this landscape enhances ponding on the colluvial slopes and alluvial plains, and results in land salinisation in lower parts of the landscape.

This HGL has large (10–15 ha) seasonal salt sites that form on the colluvial midslopes, and very large salt sites (up to 20 ha) on the alluvial soils which are periodically wet. This part of the landscape is strongly influenced by drainage and the shallow water table. There is moderate to high expression of salt in this HGL and a corresponding moderate to high salt load to streams and moderate to high EC values. This HGL has a high salt storage capacity in the shallow flat-lying sediments on the broad valley floor. Clearing of vegetation has reduced the uptake of water from the enclosed basin, increasing the cycling potential for salts in the flat-lying alluvial sediments. Sodic and saline-sodic soils are a feature of this landscape.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes. Woodland vegetation remains on the cliff and minor talus slope.

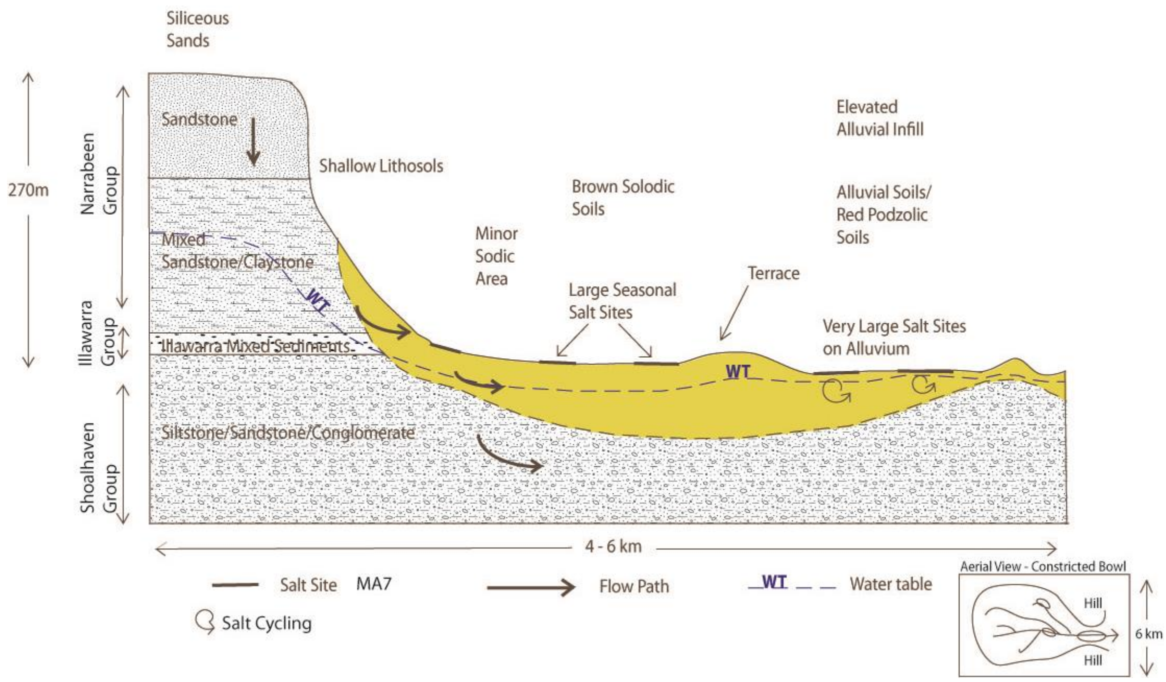


Figure 2: Conceptual cross-section for Horse Gap HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Horse Gap HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	High – large salt sites (10–15 ha, sometimes up to 20 ha) widespread on the alluvial plains, particularly when wet. Some sites also occur on low hills, rises and lower colluvial slopes where vegetation is cleared. Salt occurrence has a significant impact.
Salt Load (Export)	High – high salt store in alluvial areas. Salts can be flushed or washed off during high river flows. Low hills, rises and lower colluvial slopes also store salt with a moderate potential for export via through-flow and wash off.
EC (Water Quality)	Moderate – electrical conductivity ranges seasonally from 0.1–1.2 dS/m. Salts tend to be sodium chloride salts and bicarbonate salts. They contribute to saline water downstream along the Capertee River.

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Horse Gap HGL has high mobility. There is a high salt store that has high availability (Table 2).

Table 2: Horse Gap HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			**Horse Gap**
Moderate salt store			
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Horse Gap HGL is very high. This is due to the high likelihood that salinity issues will occur and that they would have potentially severe impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Horse Gap HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			**Horse Gap**
Moderate likelihood of occurrence			
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View facing north-east across the constricted basin towards lower mountain ridges of the Horse Gap HGL (Photo: DECCW/Rob Muller).

Photo 2: View from the Dunville Loop Road looking north, showing sandstone ridge in background and wooded hills on Illawarra Group in the centre of the Horse Gap HGL (Photo: DECCW/Luke Taylor).

Photo 3: View from the Dunville Loop Road looking east across Quaternary alluvial terraces obscuring Illawarra Group sediments, of the Horse Gap HGL (Photo: DECCW/Luke Taylor).

Table 4: Summary of information used to define Horse Gap HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Triassic and Permian periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – quartz-lithic sandstone, claystone, siltstone, minor coal • Illawarra Group (Nile subgroup) – carbonaceous shale, grey shale, thin coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through. The full stratigraphic sequence is visible on the western side of the valley. On the eastern side, the rocks associated with the Illawarra Group and Shoalhaven Group are obscured by unconsolidated alluvial terrace sediments.
Annual Rainfall	>800 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep (32–55%) to precipitous sandstone escarpments (>220 m), hills (90–200 m) and low hills (30–90 m) in the upper part of the landscape. Massive Narrabeen sandstone forms the west, north and eastern boundaries of the HGL at the catchment edges. The landscape features plateaus and escarpments and short cliff faces in the north and west, and eroded, rounded mountain tops in the east, enclosing a basin-shaped landform on three sides. There are localised rises (10–30 m) on the upper colluvial slopes, and long gently inclined lower colluvial slopes and broad flat alluvial plains, with alluvial terraces (rises), in the lower areas.

	The landscape configuration encloses a constricted basin, causing ponding and associated land salinisation on the valley floor in wetter periods. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes. Clayey sands and sandy and silty clays, with gravelly horizons, form the alluvial plains, with coarser pebbly sands and gravels forming alluvial terraces. Alluvial channel sediments are siliceous sands and pebble-bearing gravels.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes in descending order of relative elevation are Mount Tomah (toy) Wollangambe (wox), Mount Sinai (msz) Hassans Walls (hwz), Glen Alice (gaz) and Glen Alice variant a (gaza). Canobla Gap (cgy) occurs on rises on the valley floor. Mount Tomah has very little extent in this HGL. Soils above Hassans Walls soil landscape are Rudosols, Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). Hassans Walls has similar soil types but bare rock faces are common and where soil has formed it tends to be shallow. Bellow the cliff faces talus slopes have formed and soil tend to be moderately deep Yellow and Brown Kurosols (Yellow and Brown Podzolic Soils). The footslopes and drainage lines contain Brown Sodosols (solodic soils) and Brown-Grey Sodosols (Solodized Solonetz). Moderate to severe sheet erosion with the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion which is active to partially stabilised.
Rural Land Capability *(Emery 1986)*	• Classes V, IV and III on lower colluvial slopes and alluvial terraces • Classes VII and VI on timbered hill country.
Land Use	• Native forest on hills • Grazing on native and some modified pastures lower in the landscape, and some fodder cropping on alluvial plains.
Key Land Degradation Issues	• Large seasonal saline sites (<20 ha) • Sheet erosion (talus, colluvial slopes) • Seasonal waterlogging (colluvial slopes, alluvial plain) • Gullying and streambank erosion (alluvial channel).
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Horse Gap HGL is typically Heathlands and Dry Sclerophyll Forest communities on the highest ridges and plateau areas (MA1). The upper erosional slopes (MA2) support both Wet and Dry Sclerophyll Forests which grade into Dry Sclerophyll Forests and Grassy Woodlands lower down the colluvial slopes (MA2, MA3). Generally, the vegetation on Horse Gap HGL becomes increasingly dominated by Grassy Woodlands further towards the valley floor (MA4, MA6, MA9, MA10). ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Horse Gap HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Brackish. Range: 1.6–4.8 dS/m.
Depth to Water Table	Intermediate to deep. Range: 5–10 m.
Typical Sub-Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Medium (years).
Responsiveness to Change	Slow (decades).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge et al. (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Horse Gap HGL

Functions this landscape provides within a catchment scale salinity context:

- **D.** The landscape generates salt loads which enter the streams and are redistributed in the catchment
- **E.** The landscape receives and stores salt load through irrigation or surface flow
- **H.** The landscape contains high hazard for generating sodic and saline sediments.

Landscape Management Strategies – Horse Gap HGL

Appropriate strategies pertinent to this landscape:

- **Buffer the salt store (1):** There are stores of salt in discrete upper colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy, and comprise a **significant percentage** of this HGL.
- **Rehabilitate and manage discharge (4):** The saline sites are seasonal, with low to moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Key Management Focus – Horse Gap HGL

Focus is management of salinity in the bowl landscape by species selection and management. Extensive areas of saline land that are very visible, exist in wet times. Use of salt tolerant species on-site and native grasses/introduced species off-site, have the potential to increase production.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Targeting plantings at specific geological layers can buffer salt store and impact on salinity.
- Significant areas of native pastures and remnant vegetation can act as a seed source and basis for sound native systems – a large opportunity for effective results
- Discharge management – trees and salt pastures are likely to be very productive in this landscape if correct species are selected based on salinity tolerance.

Specific Land Management Constraints

Constraints on land management in this HGL include:

- Poor soil conditions that are sodic and highly erodible on benches
- Clearing will dramatically increase erosion risk, particularly on bench areas
- Pressure for small subdivision.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

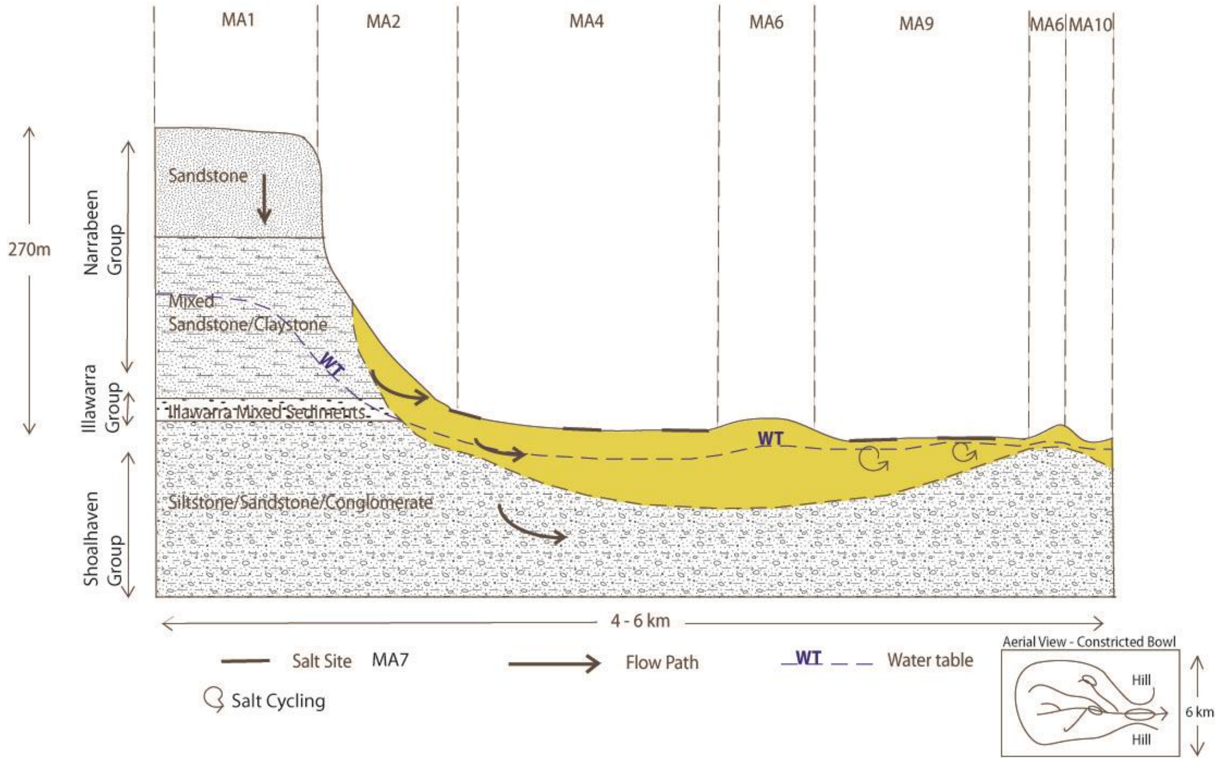


Figure 3: Management cross-section for Horse Gap HGL showing defined management areas.

Table 6: Specific management actions for management areas within Horse Gap HGL.

Management Area (MA)	Action
MA1 (Crest or ridge)	**Vegetation for ecosystem service** Maintain and improve existing native woody vegetation to reduce discharge (VE3).
MA2 (Upper slope – erosional) – steep timbered slopes – talus slope	**Vegetation for ecosystem service** Maintain and improve existing native woody vegetation to reduce discharge (VE3). Revegetate non-agricultural land with native species to manage recharge (VE6).
MA4 (Mid slope) – erosional bench – geological layers	**Vegetation for ecosystem service** Use targeted planting of trees to buffer salt stored in geological layers (VE7). Establish and manage trees to intercept lateral groundwater flow (VE3). Revegetate non-agricultural land with native species to manage recharge (VE6). **Vegetation for production**

Management Area (MA)	Action
	Improve grazing management to improve or maintain native pastures to manage recharge (VP5).
MA5 (Lower slope – colluvial)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). Maintain and improve existing native woody vegetation to reduce discharge (VP3). Establish and manage blocks of perennial forage shrubs to manage recharge (VP6). **Vegetation for ecosystem service** Establish and manage trees to intercept lateral groundwater flow (VE2). Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3). **Farming systems** Implement pasture cropping with annual cereals in perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).
MA6 (Rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3).
MA7 (Saline site)	**Sites below bench (geological sensitive area)** **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2). Fence and isolate salt land and discharge areas to promote revegetation (SR1). **Vegetation for ecosystem service** Use targeted planting of trees to buffer salt stored in geological layers (VE7). Establish and manage trees to intercept lateral groundwater flow (VE2). **Seasonal salt site** **Salt land rehabilitation**

Management Area (MA)	Action
	Establish and manage salt land pasture systems to improve productivity (SR2). **Colluvial/alluvial site** **Salt land rehabilitation** Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation (SR4). Establish and manage salt land pasture systems to improve productivity (SR2).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation to reduce discharge to streams (VE4). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Horse Gap HGL.

At Risk Management Areas	Action
MA1, MA2	Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge.
MA4	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge. **Bench** Poor soil management – chemical and biological (DLU9) – area is highly sodic and moderately saline.
MA5	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Annual cropping with annual plants (DLU3) – has the potential to fill up the soil profile and cause deep drainage. Annual cropping programs do not maximise use of available moisture in this HGL.
MA6	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge.

At Risk Management Areas	Action
MA7	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Flat contour banks (DLU12) – flat contour banks and ripping of saline sites will cause considerable degradation.

REFERENCES

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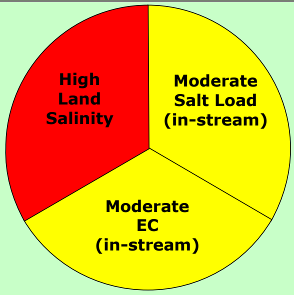
9. Marlyn Gate Hydrogeological Landscape

LOCALITIES	Marlyn Gate (NE of Mount Marsden)
MAP SHEET	Singleton 1:250 000
CONFIDENCE LEVEL	Medium



OVERVIEW

The Mount Marsden Hydrogeological Landscape (HGL) is located on the Dunville Loop, adjacent to Mount Marsden HGL in the north-west edge of the Capertee Valley. The area receives >800 mm of rain per annum.

This HGL is distinguished from most other HGLs in the Capertee Valley by the presence of a very sodic eroded landform at the base of cliff section and salinity in the lower landform. It is similar to Bourbin Hills HGL.

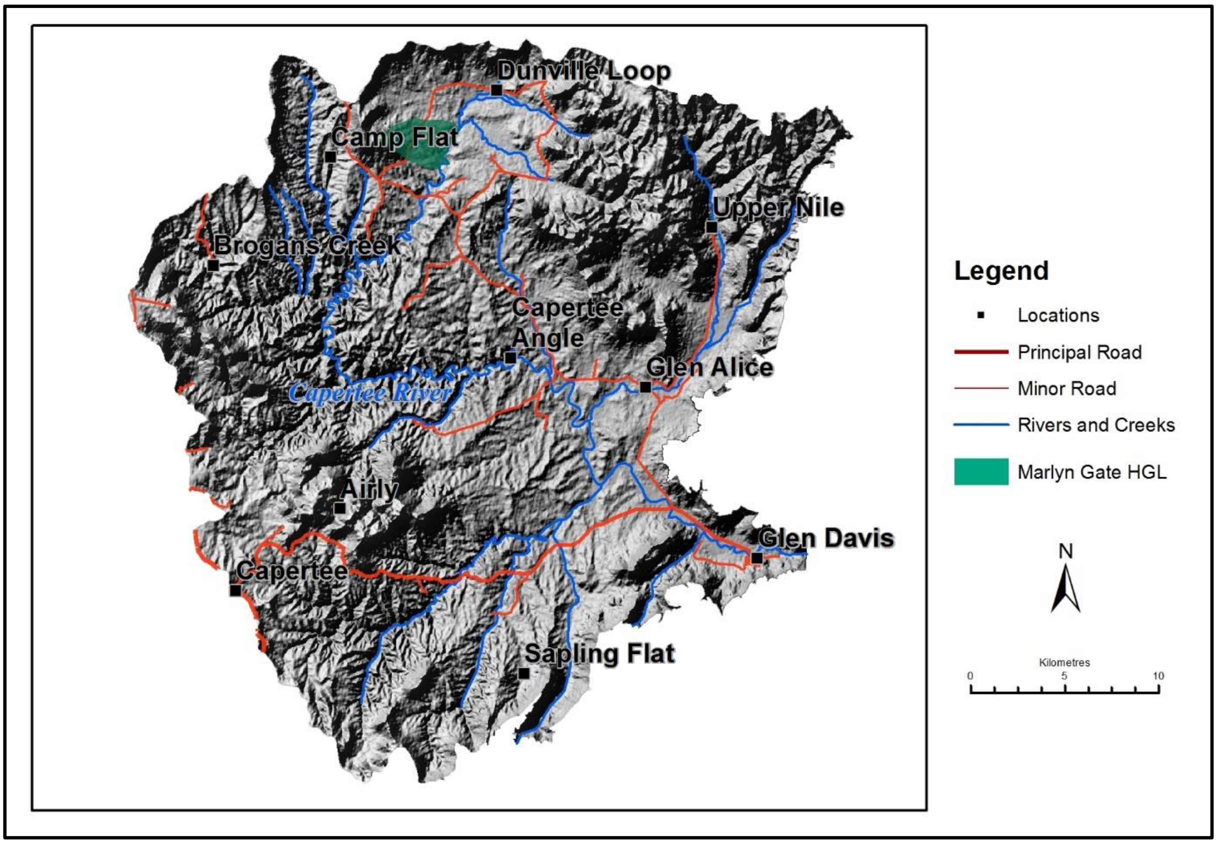


Figure 1: Marlyn Gate HGL location map.

The Marlyn Gate Hydrogeological Landscape (HGL) is characterised by flat-lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale. The landscape features a steep sandstone escarpment, a talus slope, a prominent ‘bench’ at the base of the talus slope, a long colluvial slope with localised rises and a narrow alluvial plain adjacent to the drainage line.

Water infiltrates through the plateau surface high in the landscape. It moves through the fractured sedimentary rock sometimes emerging at horizontal fractures as cliff-face springs. As water percolates downward along structures (joints, fractures, faults) in the rock it may encounter less permeable layers in the stratigraphy and flow laterally along these layers. Low in the landscape, lateral flow across bedding in the Illawarra and Shoalhaven Groups causes stored salt to mobilise. Shallow subsurface water flow also occurs through the unconsolidated rocky sediments forming the talus slope and through colluvial materials lower in the landscape. Soil texture changes (lithic gravels and sands to sandy clay) at changes in slope may impede flow and result in water emerging at the surface during wetter periods.

This HGL has large salt sites (<4 ha) that form below the rises at the base of the talus slope where there is a texture contrast and a slope change. Small (<2 ha) seasonal saline scalds are also present lower on the colluvial slopes, and adjacent to drainage lines (<0.5 ha). There is a notable expression of salt in this HGL and a corresponding moderate salt load to streams and moderate EC values. There is severe erosion on a poorly vegetated ‘bench’ with sodic soils (Soloths) at the base of the talus slope.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes. Woodland vegetation remains on the cliff and talus slopes.

Landscape limitations and hazards include steep slopes and rockfall on cliff sections high in the landscape, sheet erosion on the talus areas, and severe gully and sheet erosion on dispersive soils on a ‘bench’ at the base of the talus slope. Large saline scalds (<4 ha) are present below this ‘bench’, where there is a texture contrast and a slope change. There is minor gully erosion on lower colluvial slopes, with localised small saline scalds (0.5–2 ha), and seasonal waterlogging in the lower parts of the landscape.

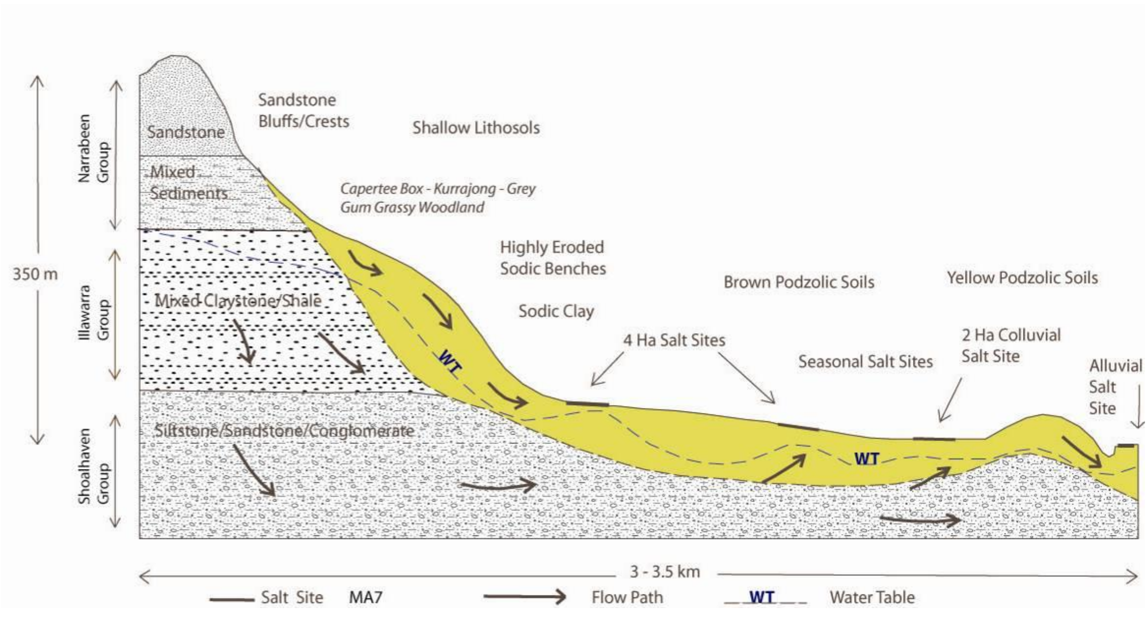


Figure 2: Conceptual cross-section for Marlyn Gate HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Marlyn Gate HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	High – saline scalds (<4 ha) on colluvial slopes, with smaller seasonal sites (<2 ha) on lower colluvial slopes, and adjacent to the alluvial channel (<0.5 ha). A prominent bench at the base of the talus slope is sodic and highly erodible. Vegetation on this bench is characterised by sparse Kurrajong *(Brachychiton sp.)* stands.
Salt Load (Export)	Moderate – constant flux from saline sites.
EC (Water Quality)	Moderate – electrical conductivity ranges from <0.8–1.8 dS/m.

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Marlyn Gate HGL has moderate mobility. There is a moderate salt store that has moderate availability (Table 2).

Table 2: Marlyn Gate HGL salt store and availability.

SALT MOBILITY	**Low** availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store		**Marlyn Gate**	
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Marlyn Gate HGL is high. This is due to the high likelihood that salinity issues will occur and that they would have potentially significant impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Marlyn Gate HGL.

OVERALL SALINITY HAZARD	**Limited** potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence		**Marlyn Gate**	
Moderate likelihood of occurrence			
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View looking west showing the rounded sandstone escarpment, talus slope, rounded sodic bench of claystone and shale and colluvial slopes of the Marlyn Gate HGL. Notice that the Kurrajong trees (distinctive light green colouring) are associated with the benches (Photo: DECCW/Rob Muller).

Photo 2: View looking south-west, showing rounded and highly eroded sodic bench of claystone and shale in the background and lower slopes in the foreground, of the Marlyn Gate HGL (Photo: DECCW/Victoria Cull).

Photo 3: View to the south-east, looking downslope at the footslopes and drainage lines of the Marlyn Gate HGL. Salt sites seasonally occur on these areas (Photo: DECCW/Yvonne Preston).

Table 4: Summary of information used to define Marlyn Gate HGL.

Lithology *(Rasmus et al.1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Triassic and Permian periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – quartz-lithic sandstone, claystone, siltstone, minor coal • Illawarra Group (Nile subgroup) – carbonaceous shale, grey shale, thin coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through.
Annual Rainfall	>800 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep (32–55%) to precipitous sandstone mountain escarpments (>220 m), hills (100–200 m) and low hills (30–100 m) in the upper part of the landscape, with rises (10–30 m), colluvial slopes and narrow alluvial plains in the lower parts of the landscape. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape. Sandy silts and clays form sodic and highly erodible materials over a prominent 'bench' at the base of the cliff and talus section. Lithic gravelly sands and sandy clays form on colluvial slopes and alluvial plains.

Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes in descending order of relative elevation are Wollangambe (wox), Hassans Walls (hwz), Glen Alice (gaz), Glen Alice variant a (gaza) and Umbiella (umy). Canobla Gap (cgy) occurs on rises of the valley floor. Soil types include shallow Lithic Rudosols (Siliceous Sands and Lithosols) on the crests with Yellow Kandosols (Earthy Sands) on sideslopes, and moderately deep Kandosols (Earthy Sands and Red and Yellow Earths) further downslope; Chromosols and Kurosols (Gleyed and Yellow Podzolic Soils) on shale lenses. On lower slopes soil types include Yellow and Brown Kurosols (Yellow and Red Podzolic Soils). Drainage lines contain Brown Sodosols (solodic soils) and Brown-Grey Sodosols (Solodized Solonetz). Stratic Rudosols and Tenosols (Alluvial Soils) occur on floodplains. There is moderate to severe sheet erosion with the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion is active to partially stabilised.
Rural Land Capability *(Emery 1986)*	• Class VIII on cliff sections • Classes VII and VI on timbered foothills • Class IV on colluvial slopes • Class V for localised (sensitive) areas particularly on the bench at the base of the cliff and talus section and associated with the large saline scalds on the upper colluvial slopes.
Land Use	• Native forest on steeper areas • Grazing on native and some modified pastures with localised fodder cropping on lower colluvial slopes.
Key Land Degradation Issues	• Steep slopes • Sheet erosion (talus areas) • Severe erosion (bench at base of talus slope) • Dispersive soils (bench at base of talus slope) • Large saline scalds (<4 ha) (upper colluvial slopes).
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Marlyn Gate HGL is typically Dry Sclerophyll Forests on ridges and plateau areas (MA1 and MA2). The erosional and upper colluvial slopes (MA2 and MA4) support Dry Sclerophyll Forests which grade into Grassy Woodlands lower down the colluvial slopes. The lower slopes (MA5), rises (MA6) and riparian zone (MA10) solely support Grassy Woodland communities and agricultural grazing. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Marlyn Gate HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Brackish. Range: 1.6–4.8 dS/m.
Depth to Water Table	Intermediate to deep. Range: 5–10 m.
Typical Sub-Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Medium (years).
Responsiveness to Change	Slow (decades).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Marlyn Gate HGL

Functions this landscape provides within a catchment scale salinity context:

- **D.** The landscape generates salt loads which enter the streams and are redistributed in the catchment
- **E.** The landscape receives and stores salt load through irrigation or surface flow
- **H.** The landscape contains high hazard for generating sodic and saline sediments.

Landscape Management Strategies – Marlyn Gate HGL

Appropriate strategies pertinent to this landscape:

- **Buffer the salt store (1):** There are stores of salt in discrete upper colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy, and comprise a significant percentage of this HGL.
- **Rehabilitate and manage discharge (4):** The saline sites are seasonal, with low to moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Key Management Focus – Marlyn Gate HGL

Focus is on grazing and salinity management on the lower slopes, with management of the eroded saline bench being of major importance. The area is highly eroded. The use of high rates of mulch, have been used successfully in similar landscape situations.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Targeting plantings at specific geological layers can buffer salt store and impact on salinity
- Significant areas of native pastures and remnant vegetation can act as a seed source and basis for sound native systems – a large opportunity for effective results
- Discharge management – trees and salt pastures are likely to be very productive in this landscape if correct species are selected based on salinity tolerance.

Specific Land Management Constraints

Constraints on land management in this HGL include:

- Poor soil conditions that are sodic and highly erodible on benches
- Clearing will dramatically increase erosion risk, particularly on bench areas
- Pressure for small subdivision.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

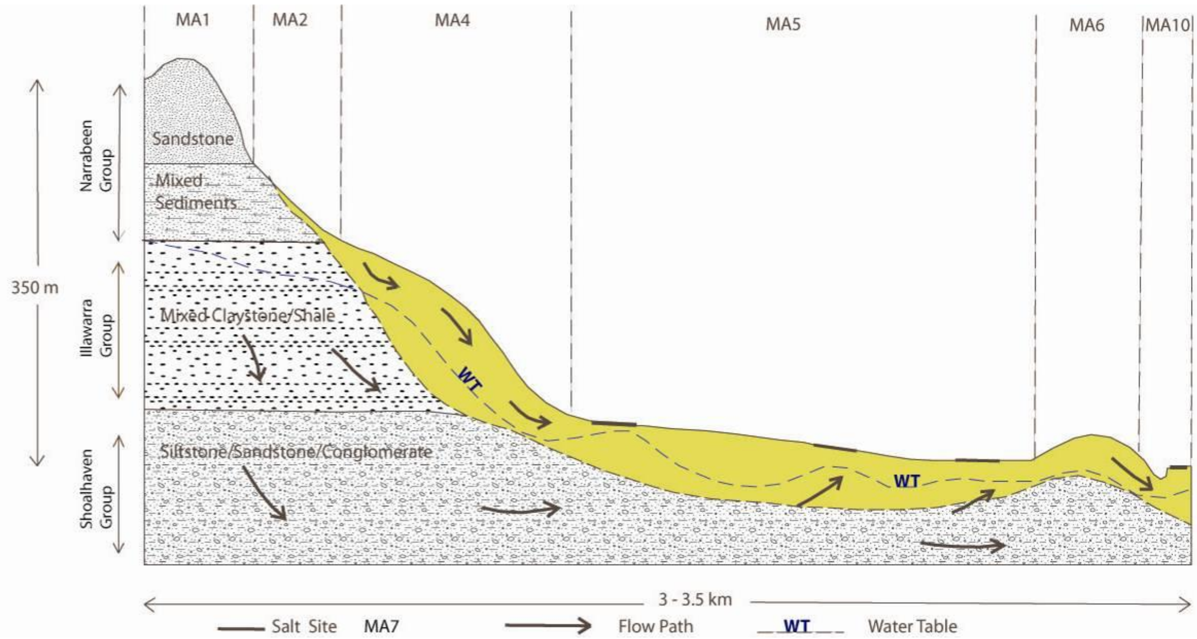


Figure 3: Management cross-section for Marlyn Gate HGL showing defined management areas.

Table 6: Specific management actions for management areas within Marlyn Gate HGL.

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MA2 (Upper slope – erosional) – steep timbered slopes – talus slope	**Vegetation for ecosystem service** Maintain and improve existing native woody vegetation to reduce discharge (VE3). Revegetate non-agricultural land with native species to manage recharge (VE6).
MA4 (Mid slope) – erosional bench – geological layers	**Vegetation for ecosystem service** Use targeted planting of trees to buffer salt stored in geological layers (VE7). Establish and manage trees to intercept lateral groundwater flow (VE3). Revegetate non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Improve grazing management to improve or maintain native pastures to manage recharge (VP5).
MA5 (Lower slope – colluvial)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1).

Management Area (MA)	Action
	Improve grazing management to improve or maintain native pastures to manage recharge (VP5). Maintain and improve existing native woody vegetation to reduce discharge (VP3). Establish and manage blocks of perennial forage shrubs to manage recharge (VP6). **Vegetation for ecosystem service** Establish and manage trees to intercept lateral groundwater flow (VE2). Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3). **Farming systems** Implement pasture cropping with annual cereals in perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).
MA6 (Rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3).
MA7 (Saline site)	**Sites below bench (geological sensitive area)** **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2). Fence and isolate salt land and discharge areas to promote revegetation (SR1). **Vegetation for ecosystem service** Use targeted planting of trees to buffer salt stored in geological layers (VE7). Establish and manage trees to intercept lateral groundwater flow (VE2). **Seasonal salt site** **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2). **Colluvial/alluvial site** **Salt land rehabilitation** Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation (SR4).

Management Area (MA)	Action
	Establish and manage salt land pasture systems to improve productivity (SR2).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation to reduce discharge to streams (VE4). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Marlyn Gate HGL.

At Risk Management Areas	Action
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MA5	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Annual cropping with annual plants (DLU3) - has the potential to fill up the soil profile and cause deep drainage. Annual cropping does not maximise use of available moisture in this HGL.
MA6	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge.
MA7	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Flat contour banks (DLU12) – flat contour banks and ripping of saline sites will cause considerable degradation.

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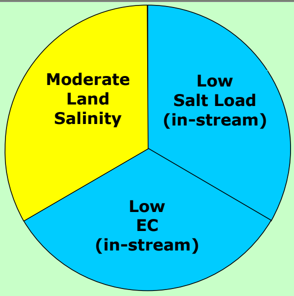
10. Mount Marsden Hydrogeological Landscape (incorporating Home Hills HGL)

LOCALITIES	**Mount Marsden and Home Hills Road**
MAP SHEET	**Singleton 1:250 000 Dubbo 1:250 000 Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Mount Marsden Hydrogeological Landscape (HGL) is located at Mount Marsden and the north-west edge of the Capertee Valley HGL map area. The area receives >800 mm of rain per annum.

The poorly vegetated and eroded bench at the base of the cliff section in the Marlyn Gate HGL is not observed in this HGL. However there is a large open, low hills area along Home Hills Road that has a distinctive ‘plateau’ shape of Shoalhaven Group-Berry formation rocks.

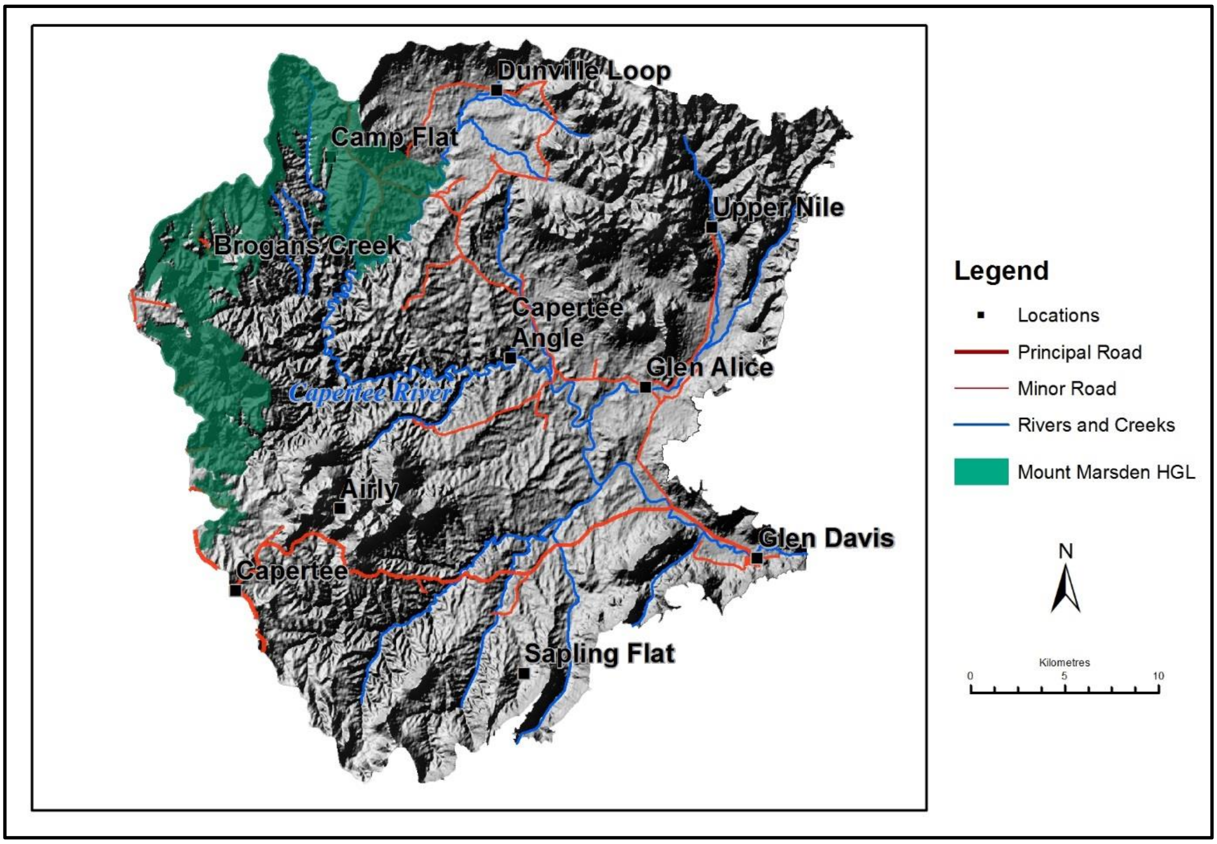


Figure 1: Mount Marsden HGL location map.

Mount Marsden HGL is characterised by flat lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale within the Capertee Valley at Mount Marsden. The landscape features a steep sandstone escarpment, a talus slope, a long colluvial slope with localised rises and a narrow alluvial plain adjacent to the drainage line.

Water infiltrates through the plateau surface high in the sandstone landscape. It moves through the fractured sedimentary rock sometimes emerging at horizontal fractures as cliff-face springs. As water percolates downward along structures (joints, fractures, faults) in the rock it may encounter less permeable layers in the stratigraphy and flow laterally along these layers. Low in the landscape, lateral flow across bedding in the Illawarra and Shoalhaven Groups causes stored salt to mobilise. Shallow subsurface water flow also occurs through the unconsolidated rocky sediments forming the talus slope and through colluvial materials lower in the landscape. Soil texture changes (lithic gravels and sands to sandy clay) at changes in slope may impede flow and result in water emerging at the surface during wetter periods.

This HGL has small (<1 ha) salt sites that form at the base of the talus slope where there is a texture contrast and slope change. Small seasonal saline scalds are seen lower on the colluvial slopes and adjacent to drainage lines. Due to the limited expression of salt in this HGL, salt load and EC in streams is also low.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes. Woodland vegetation remains on the cliff and talus slopes.

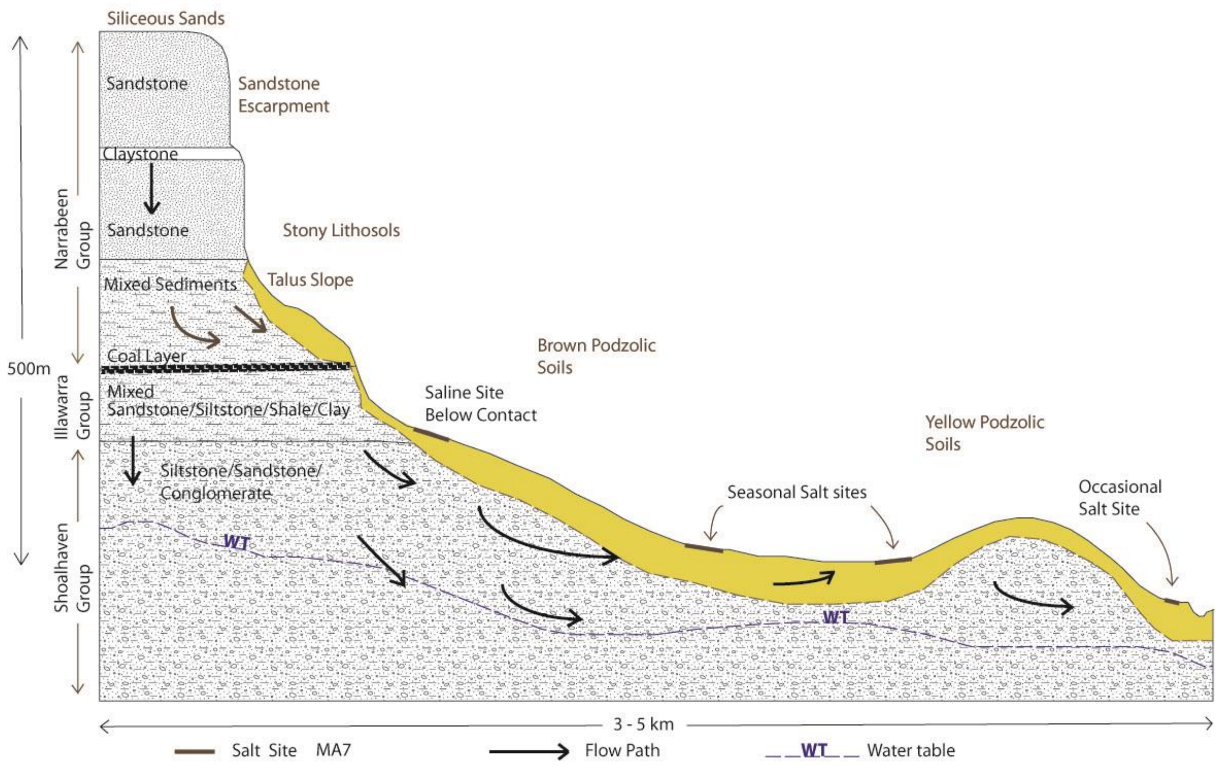


Figure 2: Conceptual cross-section for Mount Marsden HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Mount Marsden HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Moderate – small localised salt sites associated with landscape depressions and changes in slope lower in landscape. Typically NaCl sites. Small sites <0.5 ha.
Salt Load (Export)	Low – relatively high rainfall and low salt store in this landscape.
EC (Water Quality)	Low – high quality fresh water (<0.8 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Mount Marsden HGL has low mobility. There is a low salt store that has moderate availability (Table 2).

Table 2: Mount Marsden HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store		**Mount Marsden**	

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Mount Marsden HGL is low. This is due to the low likelihood that salinity issues will occur and that they would have potentially significant impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Mount Marsden HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence		**Mount Marsden**	

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Dunville Loop Road facing north-west showing Mount Marsden and talus slope of the Mount Marsden HGL (Photo: DECCW/Luke Taylor).

Photo 2: View from Dunville Loop Road facing south-east and looking downslope onto the lower colluvial slopes of Mount Marsden (fore and mid ground) of the Mount Marsden HGL (Photo: DECCW/Luke Taylor).

Photo 3: View from Glen Alice Road facing north, showing the alluvial plain of Mount Marsden at the Capertee River, of the Mount Marsden HGL (Photo: DECCW/Luke Taylor).

Table 4: Summary of information used to define Mount Marsden HGL.

Lithology *(Rasmus et al. 1969; Raymond et al. 1998; Colquhoun et al. 1999; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Triassic and Permian periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – quartz-lithic sandstone, claystone, siltstone, minor coal • Illawarra Group (Nile subgroup) – carbonaceous shale, grey shale, thin coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through.
Annual Rainfall	>800 mm.
Regolith and Landforms	This HGL is characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. The resistant Narrabeen Sandstone forms a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope. Gradients of the steep to precipitous sandstone mountain escarpments range from 32 to 55%. Lower in the landscape low hills (30–100 m) and rises (10–30 m) form a small area of hummocky ground that opens onto a low gradient colluvial slope adjacent to the relatively narrow alluvial plain of the upper Bogee Creek. Regolith materials are moderately weathered. Angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands are dominant in the upper parts of the landscape. Lithic gravelly sands and sandy clays

	occur on colluvial slopes. Silcrete is present in localised areas on the lower colluvial slopes, developed on siliceous lithic gravels derived from the Shoalhaven Group sediments.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soils landscapes from the highest relative elevation to the lowest are Medlow Bath (mbz), Hassans Walls (hwz), Glen Alice (gaz) and Glen Alice variant a (gaza). Hassans Walls forms a steep relatively short sandstone escarpment that separates the plateau from the long lower colluvial slopes and a broad alluvial plain. Canobla Gap (cgy) occurs on rises of the valley floor. Soil types include shallow Lithic Rudosols (Siliceous Sands and Lithosols) on the crests with Yellow Kandosols (Earthy Sands) on sideslopes, and moderately deep Kandosols (Earthy Sands and Red and Yellow Earths) further downslope; Chromosols and Kurosols (Gleyed and Yellow Podzolic Soils) on shale lenses. On lower slopes soil types include Yellow and Brown Kurosols (Yellow and Red Podzolic Soils). Drainage lines contain Brown Sodosols (solodic soils) and Brown-Grey Sodosols (Solodized Solonetz). Stratic Rudosols and Tenosols (Alluvial Soils) occur on floodplain elements. There is moderate to severe sheet erosion with the A1 horizon (topsoils) absent on a few steeper slopes. Localised gully erosion is active to partially stabilised.
Rural Land Capability *(Emery 1986)*	• Class VIII on cliff sections • Classes VII and VI on timbered foothills • Class IV on colluvial slopes • Class V for localised (sensitive) areas.
Land Use	• Native forest remains on hill slopes (e.g. Nattai National Park, Blue Mountains National Park) • Grazing on native and some modified pastures on the rolling rises and low hill crests, and on cleared land low in the landscape • Some forest reserves are present on valley floor rises.
Key Land Degradation Issues	• Moderate to severe sheet erosion in some steeper areas of the landscape • Localised gully erosion.
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation on the highest ridges and plateau areas of the Mount Marsden HGL is typically Heathlands and Dry Sclerophyll Forest communities (MA1) reflecting the sandstone substrate and the exposed aspect on the high sandstone cliff areas (>900 m ASL). There is a distinct vegetation change from the sandstone ridges to the upper erosional and colluvial slopes (MA2/3) where the higher altitude shrubby forests and woodlands merge into Wet Sclerophyll Forests. This narrow band of Wet Sclerophyll Forests grades downslope into Dry Sclerophyll Forests and then Grassy Woodlands on the mid and lower colluvial slopes (MA4, MA5). The rises (MA6) on the valley plain and the Riparian – Alluvial Channel areas (MA10) closer to the Capertee River are dominated by Grassy Woodlands. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Mount Marsden HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	High. Range: >10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate to high. Range: 5–>15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Marginal to brackish. Range: 0.8–4.8 dS/m
Depth to Water Table	Intermediate to deep. Range: 5–10 m.
Typical Sub-Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Mount Marsden HGL

Functions this landscape provides within a catchment scale salinity context:

- **B.** The landscape provides fresh water runoff as an important dilutions flow source
- **C.** The landscape provides important base flow to local streams.

Landscape Management Strategies – Mount Marsden HGL

Appropriate strategies pertinent to this landscape:

- **Buffer the salt store (1):** There are stores of salt in discrete upper colluvial areas, which vegetation can buffer, limiting salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy, and comprise a very small percentage of this HGL.
- **Rehabilitate and manage discharge (4):** The saline sites are seasonal, with low to moderate severity. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.
- **Maintain or maximise runoff (10):** This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.

Key Management Focus – Mount Marsden HGL

The focus is primarily on vegetation and grazing management. There is significant native vegetation across the landscape especially in steeper slopes. There are grass stands across the lower landscape, primarily on the Shoalhaven Group sediments. Salt sites are small and readily rehabilitated.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- The landscape is essentially wooded, with minor salinity
- There is a defined slope change where salinity actions can be targeted
- Targeting plantings at specific geological layers can buffer salt store and impact on salinity
- Fresh water catchment that dilutes the impacts of the salinity contributions of other catchments.

Specific Land Management Constraints

Constraints on land management in this HGL include:

- Poor soil conditions that are sodic and highly erodible in only some locations
- Pressure for small subdivision
- Colluvial areas which are salty and wet for long periods in winter retard plant growth.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

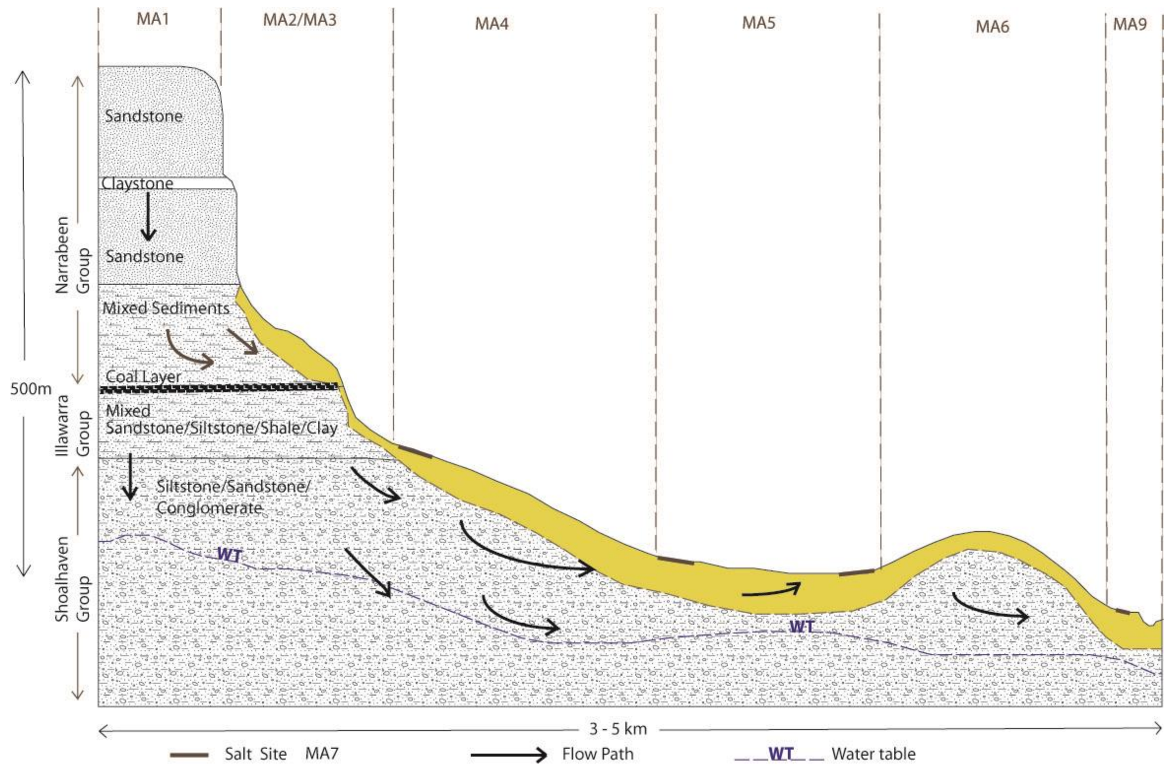


Figure 3: Management cross-section for Mount Marsden HGL showing defined management areas.

Table 6: Specific management actions for management areas within Mount Marsden HGL.

Management Area (MA)	Action
MA1 (Crest or ridge) – flat topped escarpment	**Vegetation for ecosystem service** Maintain and improve existing native woody vegetation to reduce discharge (VE3).
MA2 (Upper slope – erosional) – steep timbered slopes **MA3** (Upper slope – colluvial) – talus slope – geological layers	**Vegetation for ecosystem service** Maintain and improve existing native woody vegetation to reduce discharge (VE3). Use targeted planting of trees to buffer salt stored in geological layers (VE7). Revegetate non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Improve grazing management to improve or maintain native pastures to manage recharge (VP5).
MA4 (Mid slope)	**Vegetation for production**

Management Area (MA)	Action
	Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). Establish and manage perennial pastures to manage recharge (VP2). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2). **Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (VE6). Establish and manage trees to intercept lateral groundwater flow (VE3).
MA5 (Lower slope – colluvial)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). Maintain and improve existing native woody vegetation to reduce discharge (VP3). Establish and manage blocks of perennial forage shrubs to manage recharge (VP6). **Vegetation for ecosystem service** Establish and manage trees to intercept lateral groundwater flow (VE2). Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3). **Farming systems** Implement pasture cropping with annual cereals in perennial pastures to manage recharge (FS1). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).
MA6 (Rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Improve grazing management to improve or maintain native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (VE6). Maintain and improve existing native woody vegetation to reduce discharge (VE3).
MA7 (Saline site)	**Sites at contact with geological sensitive area** **Salt land rehabilitation**

Management Area (MA)	Action
	Establish and manage salt land pasture systems to improve productivity (SR2). Fence and isolate salt land and discharge areas to promote revegetation (SR1). **Vegetation for ecosystem service** Use targeted planting of trees to buffer salt stored in geological layers (VE7). Establish and manage trees to intercept lateral groundwater flow (VE2). **Vegetation for production** Maintain and improve existing native woody vegetation to reduce discharge (VP3). **Seasonal salt site** **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2). **Colluvial/alluvial site** **Salt land rehabilitation** Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation (SR4). Establish and manage salt land pasture systems to improve productivity (SR2).
MA9 (Alluvial plain)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation to reduce discharge to streams (VE4). **Salt land rehabilitation** Establish and manage salt land pasture systems to improve productivity (SR2).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Mount Marsden HGL.

At Risk Management Areas	Action
MA1, MA2, MA3	Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge.
MA4	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity.
MA5	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Annual cropping with annual plants (DLU3) – has the potential to fill up the soil profile and cause deep drainage. Annual cropping does not maximise use of available moisture in this HGL.

At Risk Management Areas	Action
MA6	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Clearing and poor management of native vegetation (DLU4) – this can reduce water use by vegetation and increase rates of recharge.
MA7	Poor management of grazing pastures (DLU2) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity. Flat contour banks (DLU12) – flat contour banks and ripping of saline sites will cause considerable degradation.

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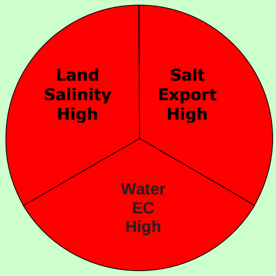
11. Nile Hydrogeological Landscape

LOCALITIES	**Nile and Umbiella Creek**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Nile Hydrogeological Landscape (HGL) is located in the Capertee Valley along the Upper Nile Road. The area receives >600 mm of rain per annum.

The HGL is highly saline with large salt sites on the valley floor, and high EC in-stream. It differs from Glen Davis HGL which looks similar, but is less saline.

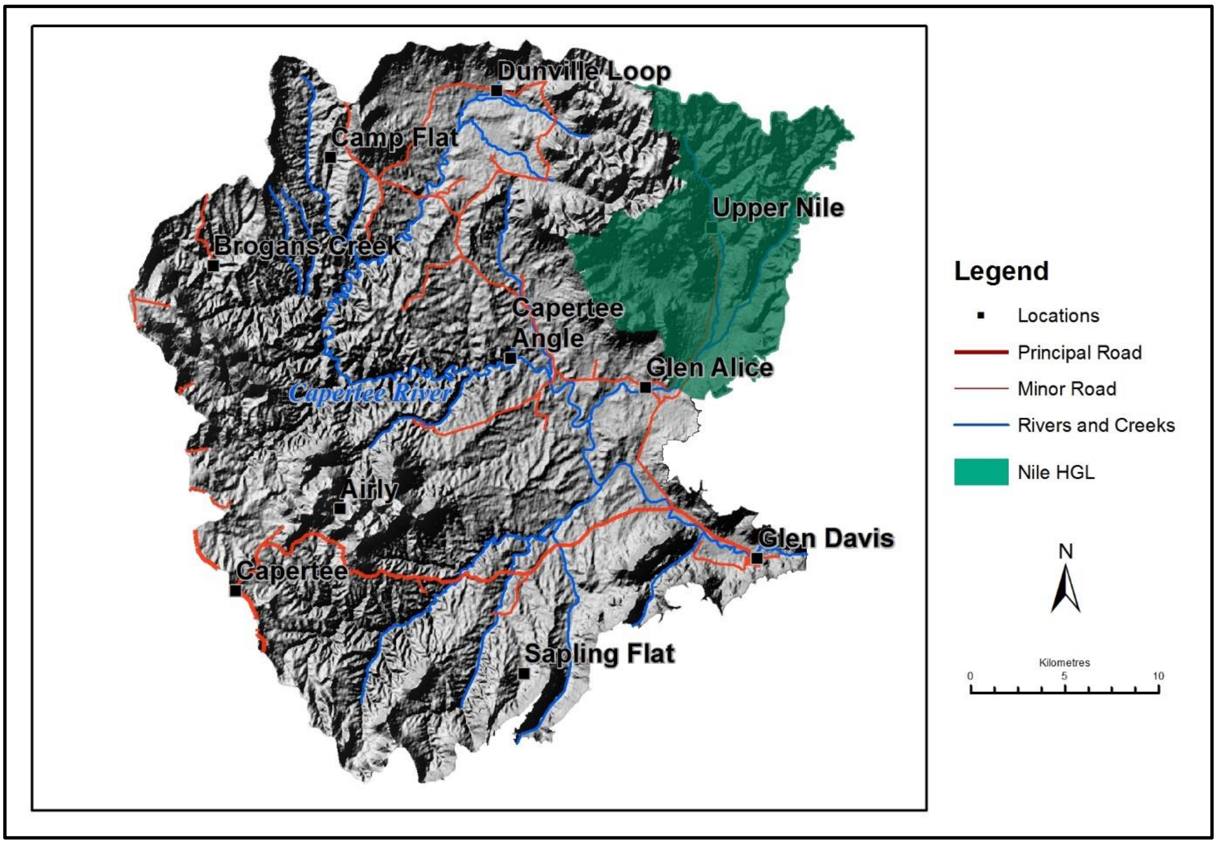


Figure 1: Nile HGL location map.

The Nile HGL is characterised by flat-lying Permo-Triassic sandstone, claystone, conglomerate and shale. The landscape features a steep sandstone escarpment, a talus slope, localised poorly vegetated erosional ‘benches’ in the west, rises on moderately inclined colluvial slopes, transitioning into gently inclined lower colluvial slopes and a broad alluvial plain adjacent to the Umbiella and Nile Creeks, especially on the western side of the valley.

Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and minor coal of the Illawarra Group, and siltstone, sandstone and conglomerates of the Shoalhaven Group, although the lower units are largely obscured by the valley floor sequence.

This landscape features resistant Narrabeen Sandstones, forming a steep cliff section, hills (90–300 m) and mountains (>300 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope and rolling rises on inclined colluvial midslopes, above a low gradient colluvial slope and the broad alluvial plain of the Umbiella and Nile Creeks.

Water infiltrates through the plateau surface, high in the landscape and the water moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Local surface water catchments are small to intermediate (100–1000 ha). The lateral movement of subsurface waters may be impeded by a soil texture change (lithic gravels and sands to sandy clay) at the change in slope. Lower in the landscape water moves laterally through the colluvial and alluvial materials, and may emerge at the land surface in wetter periods. The depth to the water table is shallow (<2 m) and the groundwater quality is brackish to saline (Typically EC 1.6 to >4.8 dS/m – but up to EC 9 dS/m).

Extremely large salt sites (<50 ha) occur along the western edge of Umbiella Creek. The sites are persistent but display seasonal variation. Smaller salt sites (2–5 ha) also occur on the mid and lower slopes west of Umbiella and Nile Creeks at changes in slope. The eastern side of the valley typically shows less expression of land salinisation, possibly because more salty units in the stratigraphy (i.e. within the Nile Subgroup of the Illawarra Group sediments) only intersect the land surface in localised areas, because the beds dip slightly to the east. The large volume of colluvial and alluvial sediments in this, slightly lower rainfall (~600 mm) part of the landscape allows for enhanced salt storage in the western Nile area.

Land use is limited to grazing on native and modified pasture on cleared colluvial slopes and alluvial plains. Localised fodder cropping is done lower in the landscape. Woodland vegetation remains on the cliff and talus slopes.

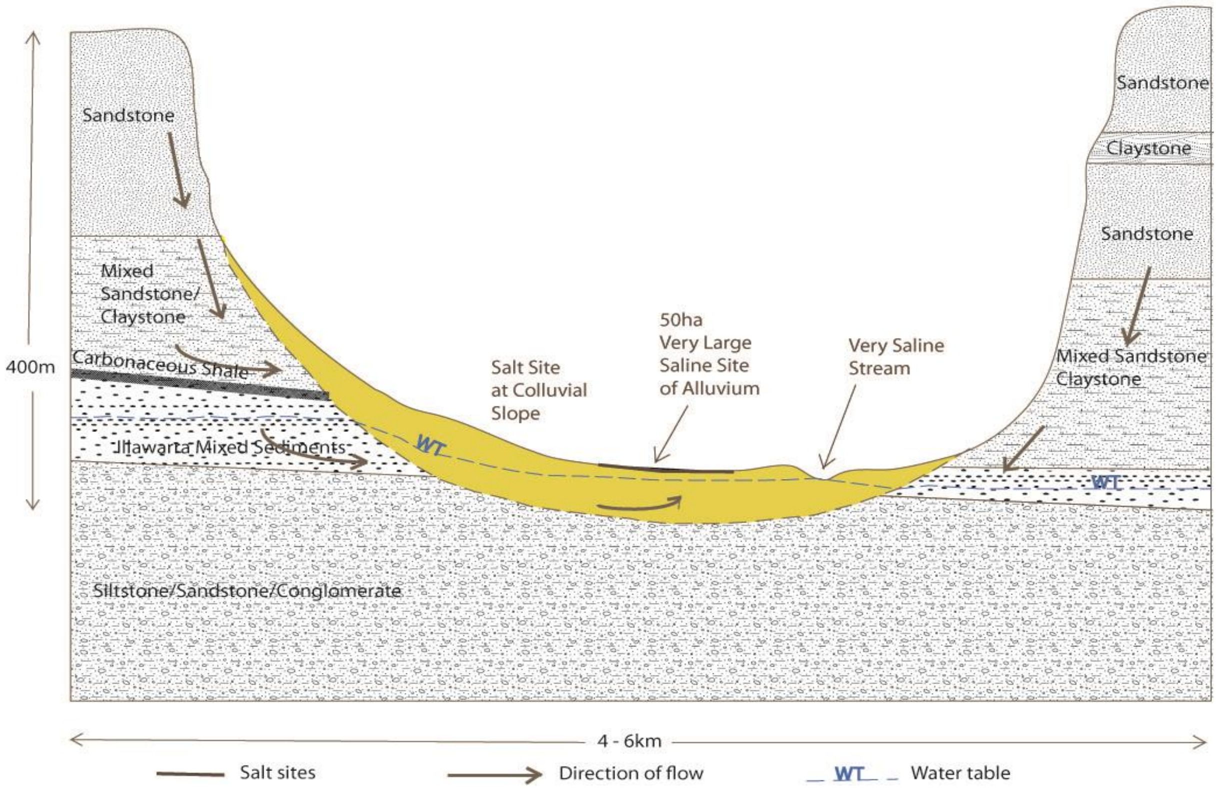


Figure 2: Conceptual cross-section for Nile HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Nile HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Land salinity is high. Extremely large salt sites (<50 ha) occur along the western edge of Umbiella Creek. The sites are persistent but display seasonal variation. Smaller salt sites (2–5 ha) also occur on the mid and lower slopes west of Umbiella Creek at changes in slope.
Salt Load (Export)	Salt export is high. Large amounts of salt are exported from the HGL.
EC (Water Quality)	High water EC. The water quality within the HGL is saline (EC <9 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Nile HGL has high mobility. There is a high salt store that has moderate availability (Table 2).

Table 2: Nile HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store		**Nile**	
Moderate salt store			
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Nile HGL is very high. This is due to the high likelihood that salinity issues will occur and that they would have potentially severe impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Nile HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			**Nile**
Moderate likelihood of occurrence			
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Upper Nile Road looking south-east towards Glen Davis, showing sandstone cliffs over colluvial slopes which grades into valley floor and Umbiella Creek, of the Nile HGL (Photo: DECCW/Victoria Cull).

Photo 2: View from Upper Nile Road looking north-west towards Glen Alice, showing sandstone cliffs over colluvial slope with salt site in the foreground of the picture, of the Nile HGL (Photo: DECCW/Victoria Cull).

Photo 3: View from Upper Nile Road looking east towards Glen Davis, showing salt scald on the western edge of Umbiella Creek, of the Nile HGL (Photo: DECCW/Victoria Cull).

Table 4: Summary of information used to define Nile HGL.

Lithology *(Bryan 1966; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group (Charbon subgroup) – claystone, siltstone, minor coal • Illawarra Group (Nile subgroup) – carbonaceous shale, grey shale, thin coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of the streams that pass through.
Annual Rainfall	~ 600 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Narrabeen and Illawarra Groups, with Shoalhaven Group sediments obscured by the colluvial and alluvial deposits in the bottom of the valley. These form steep sandstone escarpments, hills (90–200 m) and low hills (30–90 m) in the upper part of the landscape, above steep colluvial talus slopes. At the base of the talus slope, on the western side of the valley, there are localised, poorly vegetated, highly eroded 'benches' adjacent to an area of rolling rises (9–30 m) with more gently inclined lower colluvial slopes. The broad (>100 m) alluvial plain of the Umbiella and Nile Creeks forms the valley floor. Because the main drainage system is displaced to the eastern

	side of the valley, the alluvial plain is broader on the western side of the valley. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes. Clayey sand and sandy clay soils form the localised, poorly vegetated, highly eroded 'benches' on the colluvial slopes on the western side of the valley. The alluvial plains preserve gravelly sands and sandy clays to organic sandy clays.
Soil Landscapes *(DECC 2008; OEH 2017)*	This HGL is represented by parts of the Watagan (wny), Warragamba (wbz), Wollangambe (wox), Mount Sinai (msz), Medlow Bath (mbz), Newnes Plateau (npz), Mount Tomah (toy), Hassans Walls (hwz), Glen Alice (gaz) and Umbiella (umy) Soil Landscapes. The Nile HGL clifftop (Watagan, Warragamba, Wollangambe, Mount Sinai, Medlow Bath and Newnes Plateau Soil Landscapes) consists of gently inclined sandstone plateaus and erosional crests and upper slopes. Rock outcrops are common in the form of horizontal benches, cliffs and broken scarps. Relatively shallow (20–70 cm) stony Tenosols (Lithosols and Siliceous Sands) on crests with deeper (20–100 cm) Yellow Kandosols (Yellow Earths and Earthy Sands) on sideslopes; Hydrosols and Kurososls (Gleyed Podzolic and Yellow Podzolic Soils) have developed on shale lenses. The sandy clay soils of the plateaus of Medlow Bath and Newnes Plateau are relatively deep (120–200 cm). The Mount Tomah soil landscape is found on small pockets of Tertiary basalt and contain Red Ferrosols (Kransnozems) with Brown Dermosols (Chocolate Soils) and structured loams on the lower slopes. Soil types associated with the cliff faces, talus slopes and colluvial slopes (Hassans Walls Soil Landscape) include Bleached-Orthic Tenosols (Lithosols and Siliceous Sands) which give way to deeper Yellow and Brown Kurosols (Yellow and Brown Podzolic Soils) on lower slopes. The lower slopes and alluvial plains at the base of the HGL (Glen Alice Soil Landscape) contain Natric Kurosols (Soloths), Sodic Chromosols (Solodic Soils) and Red Kurosols (Red Podzolic Soils). In less well drained positions and along the drainage flats of the Umbiella and Nile Creeks Stratic Rudosols (Alluvial Soils) and Tenosols (Prairie Soils) occur (King 1992).
Rural Land Capability *(Emery 1986)*	• Classes VI, VII and VIII on upper slopes • Class IV on lower colluvial slopes • Class V on alluvial floodplains (salinised land).
Land Use	Native forest remains on hills. There is grazing on native and modified pastures lower in the landscape and fodder cropping on alluvial plains.
Key Land Degradation Issues	**Limitations**: • Land salinisation on valley flats • Localised sheet erosion • Localised gully erosion • Water erosion hazard on upper slopes • Seasonal waterlogging on valley flats

	• Localised flood hazard.
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Nile HGL is characteristic of the narrow, protected valleys that exist between high sandstone plateaus or rounded crests, their colluvial sideslopes grading into rolling rises and a broad valley floor in the east of the Capertee Valley. Vegetation supported by these valley landforms is consistent across other eastern Capertee valleys such as near Glen Davis, and hence the Nile HGL exhibits similar vegetation occurring in Glen Davis HGL. ***See Appendix C for full vegetation descriptions for each Management Area***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Nile HGL.

Aquifer Type	Unconfined in fractured rock. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Low to moderate. Range: <10^{-2}–10 m/day.
Aquifer Transmissivity	Low. Range: <2 m^2/day.
Specific Yield	Low. Range: <5%.
Hydraulic Gradient	Gentle to moderate. Range: <10–30%.
Groundwater Salinity	Brackish to saline (seasonal variation). Range: 1.6–>4.8 dS/m.
Depth to Water Table	Shallow. Range: <2 m.
Typical Catchment Size	Intermediate (100–1000 ha).
Scale (Flow Length)	Local to intermediate. Flow length: <10 km (short to intermediate).
Recharge Estimate	Low to moderate.
Residence Time	Long (decades).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Nile HGL

Functions this landscape provides within a catchment scale salinity context:

- **C.** The landscape provides important base flow to local streams
- **D.** The landscape generates salt loads which enter the streams and are redistributed in the catchment
- **E.** The landscape receives and stores salt load through irrigation or surface flow
- **F.** The landscape generates high salinity concentration water.

Landscape Management Strategies – Nile HGL

Appropriate overall strategies pertinent to this landscape:

- **Buffer the salt store (1):** There are stores of salt in discrete upper colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy, and comprise a moderate percentage of this HGL.
- **Discharge rehabilitation (4):** The saline sites are large, with moderate to high severity. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.
- **Intercept the lateral flow and shallow groundwater (2)**: This HGL can target shallow water tables that exist at the contact between underlying geology and at contacts. Rows of trees (8–30 rows) can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater.

Key Management Focus – Nile HGL

Focus is management of the saline sites on the valley floor and adjacent to the flow lines. This can be achieved by use of salt tolerant species, and grazing management. The very large salt flats can become very productive with the right species and management. Generally cleared land should be subject to grazing management practices aimed at maintaining actively growing groundcover.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Targeting planting of geological layers to buffer salt store can impact on salinity
- Significant areas of native pastures and remnant vegetation can act as a seed source and basis for sound native systems – a large opportunity for effective results

- Discharge management – trees and salt pastures are likely to be very productive in this landscape if correct species are selected based on salinity tolerance. There is a significant groundwater resource.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- The landscape is highly saline on the western side of the landscape, and essentially non saline on the east
- The flat constricted area is highly sensitive.
- Ripping of the area is likely to significantly increase erosion, salinisation and increase site recharge, which will mobilise salt to the adjacent stream
- The stream and riparian area is highly saline, in addition to high EC water entering the stream
- High Load/ Land /EC contributor, but only a small spatial area
- Species selection will require careful selection as highly salt tolerant species needed.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

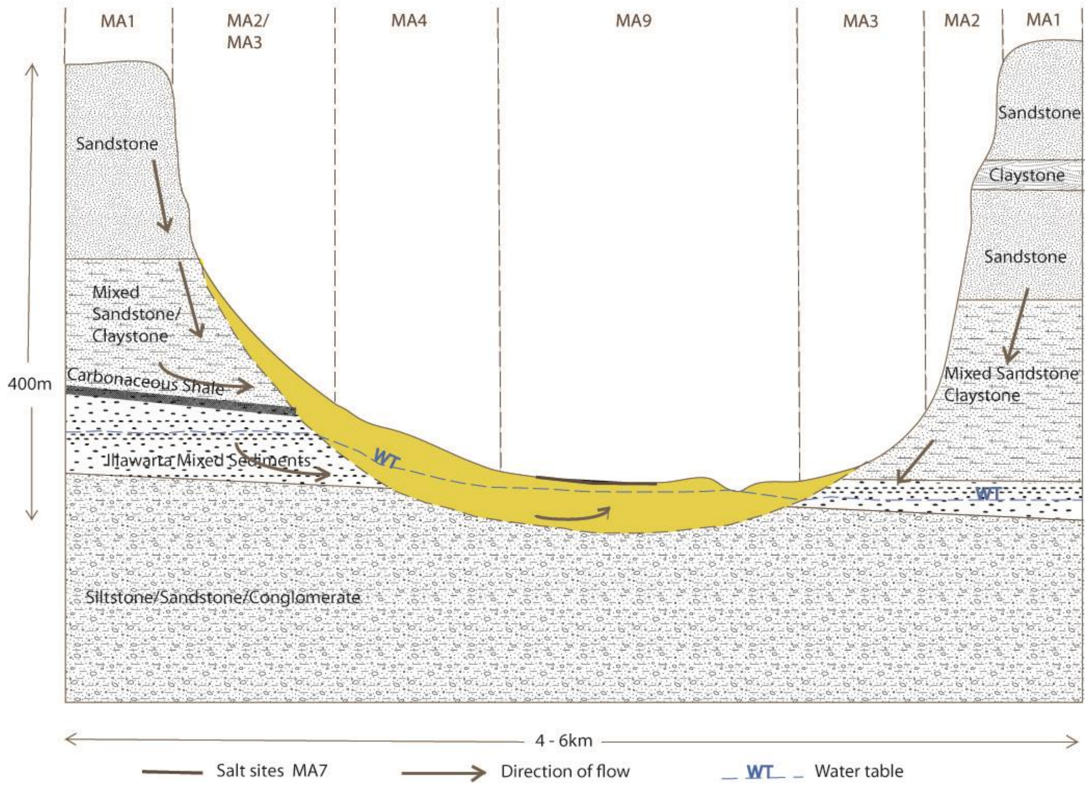


Figure 3: Management cross-section for Nile HGL showing defined management areas.

Table 6: Specific management actions for management areas within Nile HGL.

Management Area (Ma)	Action
MA1 (Cliffs) – west side	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) and **MA3** (Upper slopes – colluvial) – steep timbered slopes – talus slope (west side)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA4 (Midslopes) – geological layer (coal seam)	**Vegetation for ecosystem service** Targeted planting of geological layers to buffer salt store (VE7). Interception planting of trees to target shallow groundwater (VE2). Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5). Improve grazing management of existing perennial pastures to manage recharge (VP1). Interception of shallow lateral groundwater flow with perennial pastures (VP3). Establishment and management of perennial pastures (VP2). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA9 (Alluvial plain) – large salt sites – very saline stream	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). Establishment and management of perennial pastures (VP2). Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1).

Management Area (Ma)	Action
	Forestry for productive use of salt land (SR3). Establish and manage salt tolerant edible shrubs for productive use of salt land (SR5). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Very saline stream** **Salt land rehabilitation** Rehabilitation of salt land to minimise onsite and offsite degradation (SR4). Establish and manage salt land pasture for productive use of salt land (SR2). **Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).
MA7 (Discharge site – saline) – sites at coal seam (geological sensitive area) – colluvial salt site – very large alluvial – stream area	**Sites at coal seam (geological sensitive area)** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). **Vegetation for ecosystem service** Targeted planting of geological layers to buffer salt store (VE7). Interception planting of trees to target shallow groundwater (VE2). **Colluvial salt site** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2). **Vegetation for production** Interception of shallow lateral groundwater flow with perennial pastures (VP3). **Vegetation for ecosystem service** Interception planting of trees to target shallow groundwater (VE2). **Very large alluvial site** **Salt land rehabilitation** Rehabilitation of salt land to minimise onsite and offsite degradation (SR4). Establish and manage salt land pasture for productive use of salt land (SR2). Fence and isolate salt land and discharge areas for saline site rehabilitation (SR1). Forestry for productive use of salt land (SR3). Establish and manage salt tolerant edible shrubs for productive use of salt land (SR5). **Stream area**

Management Area (Ma)	Action
	Rehabilitation of salt land to minimise onsite and offsite degradation (SR4). Establish and manage salt land pasture for productive use of salt land (SR2).
MA3 (Upper slopes – colluvial) – east side	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5). Improve grazing management of existing perennial pastures to manage recharge (VP1).
MA2 (Upper slopes – erosional) – east side	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA1 (Cliffs) – east side	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Nile HGL.

At Risk Management Areas	Action
MA9 (Alluvial Plain)	Deep ripping of the flat alluvial soils will initiate erosion in the highly sodic subsoils, as well as increase the local recharge (DLU11). Flat contour banks and ripping of saline sites will cause considerable degradation (DLU12).
MA4 (Coal Seam)	Highly sodic area is extremely sensitive to poor soils management. Area is highly sodic and with moderate-high salinity (DLU9).
MA3, MA4, MA9	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2, MA3, MA4	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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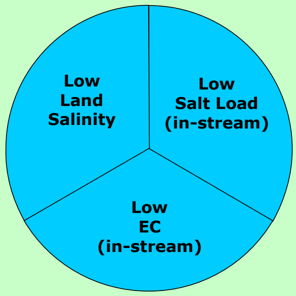
12. Port Macquarie Station Hydrogeological Landscape

LOCALITIES	**Genowlan Road** **'Port Macquarie' property entrance**
MAP SHEET	**Singleton 1:250 000** **Sydney 1:250 000** **Dubbo 1:250 000** **Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Port Macquarie Station Hydrogeological Landscape (HGL) is located in the western part of the Capertee Valley, west of Bogee, Capertee Angle and Sapling Flat. The area receives >800 mm of rain per annum.

This HGL is distinguished from most other HGLs in the Capertee Valley by its deformed and metamorphosed rocks.

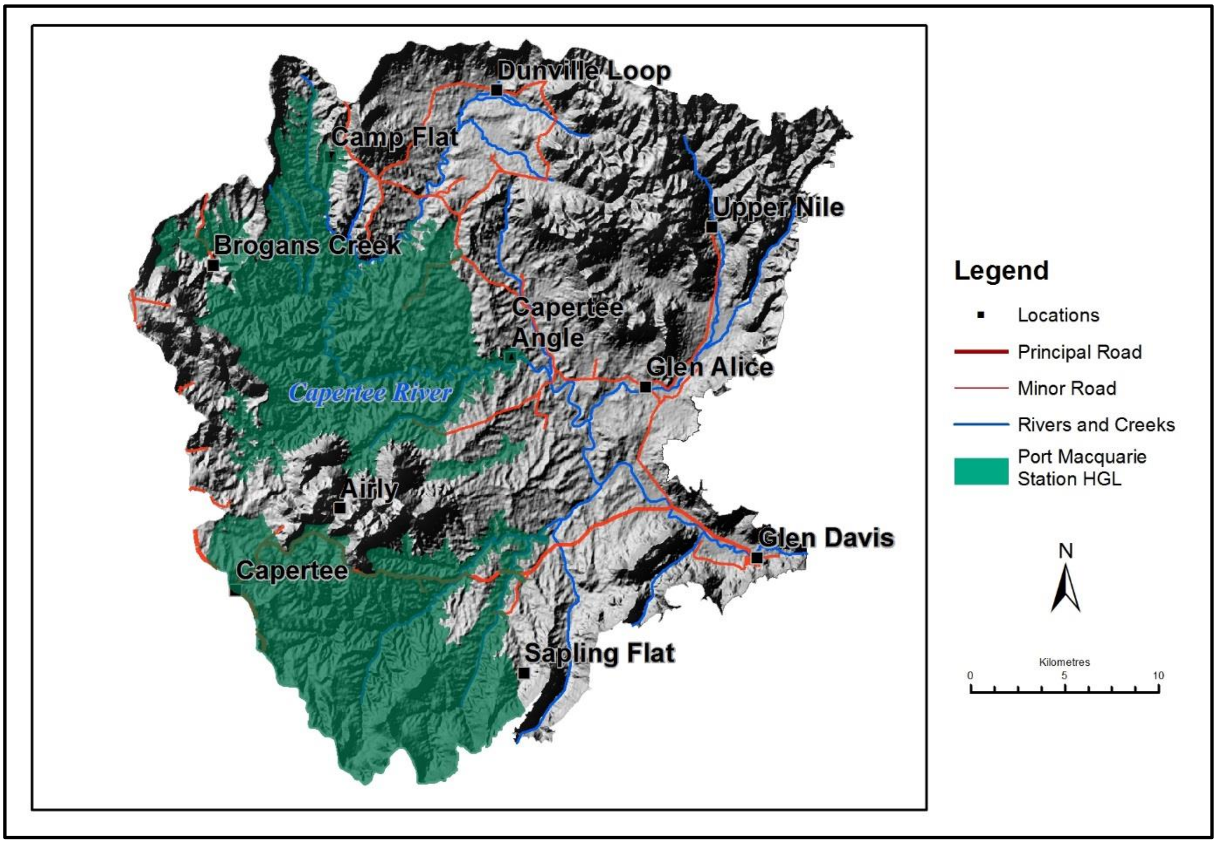


Figure 1: Port Macquarie Station HGL distribution map.

Port Macquarie Station HGL is characterised by extensive hills and low ridges with narrow crests and minor cliff sections, steep to very steep talus slopes and upper colluvial slopes, and deeply incised valleys. Lower colluvial slopes and alluvial areas are narrow, but alluvial plains typically broaden downstream.

Water runs off the steeper parts of the landscape, but in less steep areas it enters the shallow rocky soil and flows laterally through unconsolidated materials. In places water may pond behind structural features (e.g. fault zones, bedding planes). On colluvial slopes the lateral movement of subsurface water may be impeded by soil texture changes (e.g. lithic gravels and sands to more clayey gravels and sands) at the change in slope. Lower in the landscape, particularly in areas underlain by Permo-Triassic sedimentary rocks, water moves laterally through the colluvial and alluvial materials and may emerge at the land surface during wetter periods.

Salt store in this HGL is generally limited because the preserved regolith veneer is thin and cannot store much salt.

Land capability is poor due to thin and rocky soils, apart from localised areas over thin bands of calcareous sedimentary rocks.

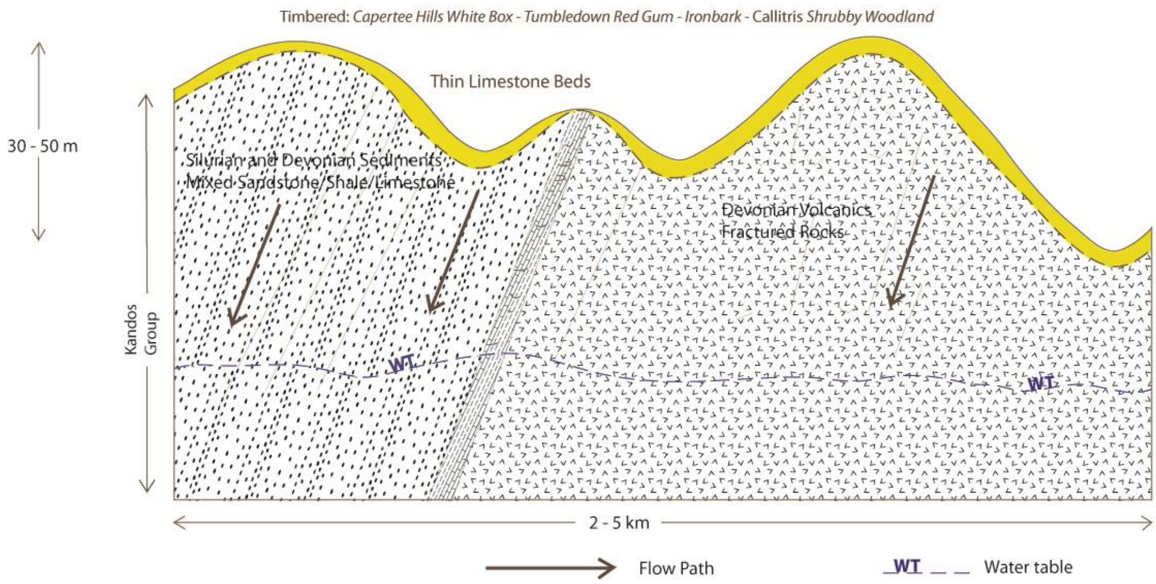


Figure 2: Conceptual cross-section for Port Macquarie Station HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is little evidence of land salinity in this HGL (Table 1).

Table 1: Port Macquarie Station HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Low – land salinisation on this HGL is limited.
Salt Load (Export)	Low – considerable flushing because of relatively high rainfall. Relatively fresh water.
EC (Water Quality)	Low – <0.8 dS/m over Siluro-Devonian rock. Relatively fresh water with some fresh to marginal measurements on the valley floor over Permo-Triassic rock (<1.6 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Port Macquarie Station HGL has low mobility. There is a low salt store that has low availability (Table 2).

Table 2: Port Macquarie Station HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store	**Port Macquarie Stn**		

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Port Macquarie Station HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Port Macquarie Station HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Port Macquarie Stn**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from the Glen Davis Road facing south showing steep vegetated hills of the Port Macquarie Station HGL (Photo: DECCW / Luke Taylor).

Photo 2: View from the Glen Davis Road showing bedded and sub-vertically cleaved Devonian geology of the landscape (Photo: DECCW / Luke Taylor).

Photo 3: View showing steep hillside and rock outcrop of the Port Macquarie Station HGL (Photo: DECCW / Fletcher Townsend).

Table 4: Summary of information used to define Port Macquarie Station HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises folded and faulted volcanic and consolidated sedimentary rocks from the Silurian and Devonian periods (Kandos Group). These are overlain by consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Kandos Group (Carwell Creek Formation) – lithic sandstone, crinoidal sandstone, shale, limestone • Kandos Group (Huntingdale Volcanic) – felsic volcanics and volcaniclastic sediments • Kandos Group (Myrtle Grove Formation) – sandstone, shale, limestone, quartzite, slate. Minor lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale • Illawarra Group – sandstone, shale, claystone and minor coal • Shoalhaven Group – siltstone, lithic sandstone, conglomerate. Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited along the floodplains of streams that pass through.
Annual Rainfall	>800 mm (decreases to the east).
Regolith and Landforms	Rock outcrop is common over most of this landscape. This HGL is characterised by deformed and variably metamorphosed Siluro-Devonian rocks. These form large areas (>100 ha) of hills (>90–300 m) and low hills (30–90 m) which form low ridges with narrow crests and minor cliff sections. There are steep (32–55%) to very steep talus slopes and upper colluvial slopes and deeply incised valleys. Lower colluvial slopes and alluvial areas are narrow but alluvial plains typically broaden downstream.

	Around the periphery of this HGL, Permo-Triassic sedimentary rocks of the Narrabeen Group form escarpments, hills and low hills above steep talus slopes. At the base of the talus slopes, there are areas of rolling rises (9-30 m), narrow lower colluvial slopes and alluvial plains. Illawarra and Shoalhaven Group sediments are largely obscured by Quaternary sediments. Regolith materials on Siluro-Devonian substrates are slightly to moderately weathered and are dominantly highly angular gravelly and coarse sands, with cobble and bouldery lithic rubble in the upper parts of the landscape. Lithic pebble- and cobble-bearing, coarse sandy gravels are found on colluvial slopes and valley floor rises. The colluvial slopes and alluvial plains preserve sandy gravels, gravelly sands and clayey coarse sands. In areas of the landscape underlain by Permo-Triassic sediments, the regolith materials are moderately weathered and dominantly angular, tabular pebble- and boulder-bearing, coarse sandy gravels and gravelly sands in the upper parts of the landscape. Lithic gravelly sands and sandy clays occur on colluvial slopes and valley floor rises. The alluvial plains preserve gravelly sands and sandy clays to organic sandy clays.
Soil Landscapes *(DECC 2008; OEH 2017)*	Many soil landscapes constitute this HGL due to two major geological groupings and a range of landforms. Glen Alice (*gaz*) Soil Landscape is the dominant Permo-Triassic unit and the second most common soil landscape within this HGL. Other soil landscapes on Permo-Triassic sedimentary rocks include Medlow Bath (*mbz*), Mount Sinai (*msz*), Hassans Walls (*hwz*), Canobla Gap (*cgy*), Umbiella (*umy*) and Rowans Hole (*roz*). Coco Soil Landscape (*cox*) is the most common soil landscape and accounts for over 90% of Siluro-Devonian rocks within this HGL. Other soil landscapes present include Port Macquarie (*pmz*). Soil types within areas of the HGL that contain Permo-Triassic rocks are widespread Tenosols (Lithosols, Structured Sands, Earthy Sands), Yellow Kandosols (Yellow Earths) and Yellow and Red Kurosols (Yellow and Red Podzolic Soils). Brown Kurosols (Solodic Soils) occur in drainage depressions and limited Red Dermosols (Terra Rossa Soils) occur on mid and lower slopes. Stratic Rudosols and Tenosols (Alluvial Soils) are found on floodplains. Hassans Walls Soil Landscape, representing the steeper Permo-Triassic areas, has minimal soil with bare rock faces common. Where soil has formed it tends to be shallow Rudosols, Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). Talus slopes and upper colluvial slopes (Hassans Walls Soil Landscape) contain Rudosols (Lithosols and Siliceous Sands) with moderately deep Yellow and Brown Kurosols (Yellow and Brown Podzolic Soils) on lower slopes. Coco Soil Landscape and other Siluro-Devonian derived soil landscapes have highly variable soil types that potentially change over a few metres. This reflects the rapid changes in lithology over short distances. Soil types include Tenosols (Lithosols) and Yellow Kurosols (Yellow Podzolic Soils). Minor gully erosion occurs along some drainage lines.
Rural Land Capability *(Emery 1986)*	• Classes VI and VII on wooded rocky hills and low hills • Class IV on cleared margins of wooded low hills and rises
Land Use	• Grazing on partially wooded native grasslands on colluvial slopes and alluvial plains

	• Localised modified pasture, particularly in areas underlain by limestone • Woodland vegetation on the crests and talus slopes (e.g. National Park, Capertee State Forest, Patoneys Crown Nature Reserve).
Key Land Degradation Issues	• Sheet erosion in the steeper parts of the landscape • Stream bank erosion along some drainage lines • Poor agricultural land (lithosols) • Minor gully erosion along some drainage lines.
Native Vegetation *(Keith 2004; DEC 2006)*	The vegetation in Port Macquarie Station HGL is a defining characteristic of this landscape unit. The rocky hills on Kandos Group sediments are unique in the surrounding landscape and the vegetation communities on this soil landscape also stand out uniquely from the surrounding landscape, coinciding with the occurrence of the substrate. Dry Sclerophyll Forest communities are ubiquitous, interspersed with Grassy Woodland pockets on limestone outcrops. The dominant Dry Sclerophyll Forest community which is prolific throughout the HGL and infrequent elsewhere in the Capertee Valley (hence a signature) is the local class of *Capertee Hills White Box – Tumbledown Red Gum – Ironbark – Callitris Shrubby Woodland* (DEC 2006). This is classified as a Western Slopes Dry Sclerophyll Forest state class. It is common in the deep gorges of the western hills of the Capertee Valley where the metamorphic rocks that lie underneath the Permian strata are exposed. The HGL also incorporates pockets of other soil landscapes that are islands either within the soil landscape or around the edges of the Port Macquarie Station unit. The decision to incorporate these areas within the Port Macquarie Station HGL was based on the common vegetation communities (that is the *Capertee Hills White Box – Tumbledown Red Gum – Ironbark – Callitris Shrubby Woodland*) occurring on the external soil landscape. Other vegetation communities also occur in pockets within the HGL on limestone soils or other soil types, although in much sparser densities. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Port Macquarie Station HGL.

Aquifer Type	Unconfined to semi-confined in fractured rock. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	Low to moderate. Range: <10^{-2}–10 m/day.
Aquifer Transmissivity	Low to moderate Range: <2–100 m^2/day.
Specific Yield	Low to moderate. Range: <5–15%.

Hydraulic Gradient	Moderate to steep. Range: 10–>30%.
Groundwater Salinity	Fresh to marginal. Range: <0.8 - 1.6 dS/m
Depth to Water Table	Intermediate to deep. Range: 2–>8 m.
Typical Sub-Catchment Size	Medium (100–1000 ha).
Scale (Flow Length)	Local (intermediate where larger scale structures are present). Flow length: <5 km (short).
Recharge Estimate	Moderate.
Residence Time	Medium (years).
Responsiveness to Change	Medium (years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Functions – Port Macquarie Station HGL

Functions this landscape provides within a catchment scale salinity context:

- **A.** The landscape provides fresh water runoff as an important water source.

Landscape Management Strategies – Port Macquarie Station HGL

Appropriate strategies pertinent to this landscape:

- **Maintain or maximise runoff (10):** This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration in the local streams.

Key Management Focus – Port Macquarie Station HGL

Focus is vegetation management on the heavily vegetated rises of the Devonian sediment. The only cleared area is in the old Port Macquarie Station that is now in a national park.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment which dilutes the impacts of the salinity contribution of other catchments
- Significant areas of native pastures and remnant vegetation can act as a seed source and basis for sound native systems – a large opportunity for effective results.

Specific Land Management Constraints

Constraints on land management in this HGL include:

- Limited constraints mainly due to high level of vegetation in the catchment and that there is little salt store to interact with fresh water.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

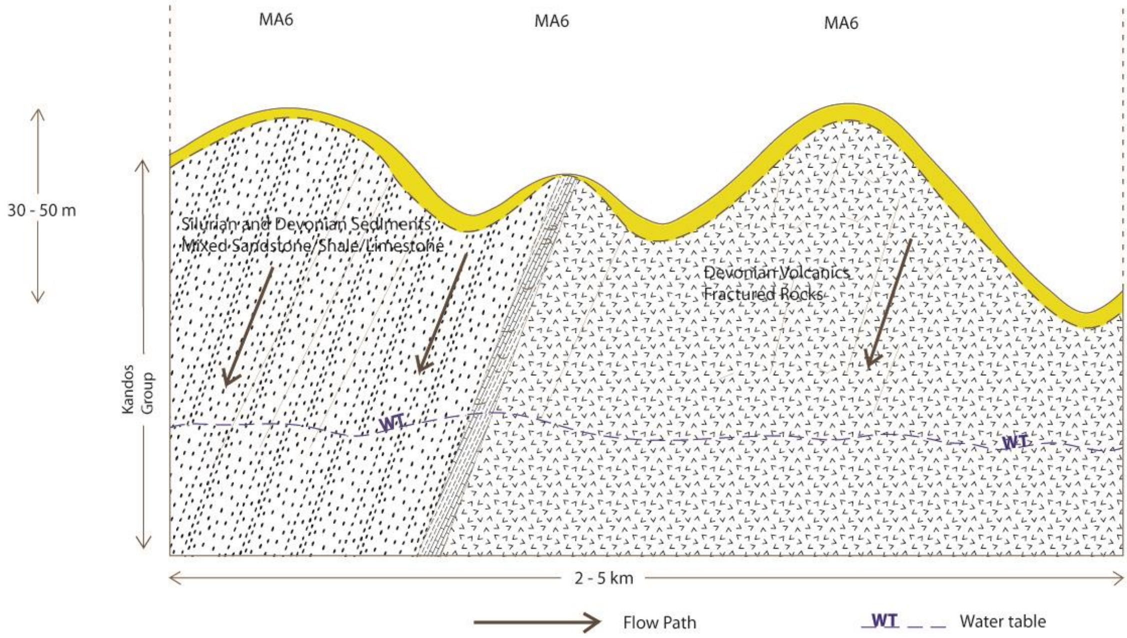


Figure 3: Management cross-section for Port Macquarie Station HGL showing defined management areas.

Table 6: Specific management actions for management areas within Port Macquarie Station HGL.

Management Area (MA)	Action
MA6 Rises *(timbered)*	**Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (**VE6**). Maintain and improve existing native woody vegetation to reduce discharge (**VE3**).

Management Area (MA)	Action
MA6 Rises *(cleared)*	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (**VP1**). Improve grazing management to improve or maintain native pastures to manage recharge (**VP5**). **Vegetation for ecosystem service** Revegetate non-agricultural land with native species to manage recharge (**VE6**). Maintain and improve existing native woody vegetation to reduce discharge (**VE3**).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Port Macquarie Station HGL.

At Risk Management Areas	Action
MA6 *(timbered)*	Clearing and poor management of native vegetation (**DLU4**) – this can reduce water use by vegetation and increase rates of recharge.
MA6 *(cleared)*	Poor management of grazing pastures (**DLU2**) – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity.

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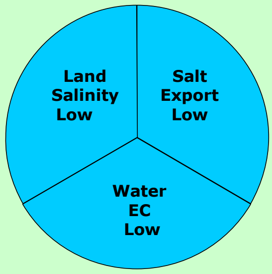
1. Hartley Hydrogeological Landscape

LOCALITIES	**Little Hartley**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Hartley Hydrogeological Landscape (HGL) is located on the eastern edge of the Hartley and Kanimbla Valleys. The area receives >900 mm of rain per annum.

The landscape has a flat valley bottom, a flat plateau top landscape and a very short escarpment.

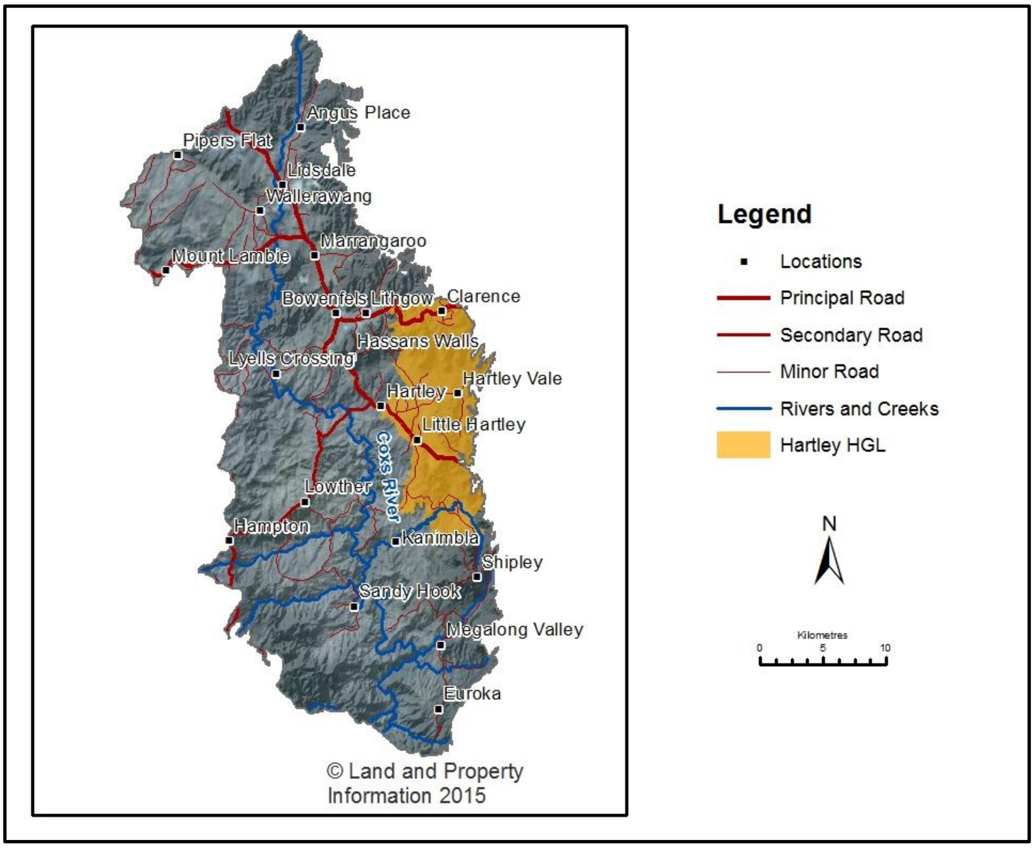


Figure 1: Hartley HGL location map.

The Hartley HGL is characterised by flat-lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale within the Hartley Valley. The landscape features a short steep sandstone escarpment, a talus slope, and a long colluvial slope with localised alluvial plain adjacent to the drainage line. Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and major coal seams of the Illawarra Group, and siltstone, sandstone and conglomerate of the Shoalhaven Group. This landscape features resistant Narrabeen Sandstones forming a short cliff section, local relief (40–200 m) and mountains (>900 m), high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope. Lower in the landscape are large low gradient colluvial slopes adjacent to relatively narrow alluvial plains and channels.

Water infiltrates through the plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Some of this groundwater will move laterally across bedding in the Illawarra Group which is low in the stratigraphy, below ground level. There may be mobilisation of salt at that level, however it is not expressed at the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Lower in the landscape water moves laterally through the colluvial materials, and may emerge at the land surface in wetter periods.

This HGL has small (<1 ha) waterlogged sites along the narrow alluvial plains and channels where there is a texture contrast and a slope change. Rare small seasonal saline scalds may be present on the colluvial slopes and adjacent to drainage lines. There is limited expression of salt in this HGL and a corresponding low salt load to streams and low EC values.

Land use is rural and rural residential on the colluvial slopes and plains. Elsewhere woodland vegetation remains on the cliff and talus slopes. Where land is largely freehold, land use is limited to grazing on native and modified pasture on cleared colluvial slopes. Disturbed lands from mining are distributed throughout this HGL.

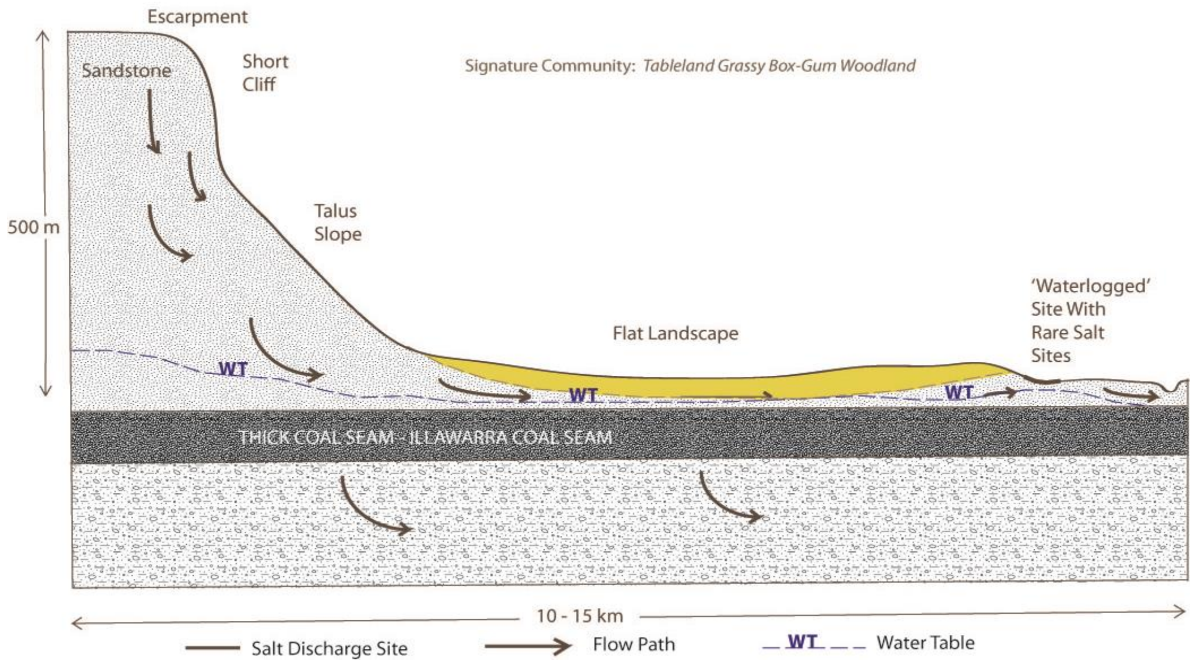


Figure 2: Conceptual cross-section for Hartley HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Hartley HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Rare small seasonal saline scalds may be on the lower colluvial slopes and adjacent to drainage lines.
Salt Load (Export)	Low salt store in this landscape. Salt store is likely to be deeper in the profile and below ground level. Mobilisation of salt may occur at that level however does not express at the land surface. Relatively fresh water.
EC (Water Quality)	High quality relatively fresh water (<0.2 dS/m)

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Hartley HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Hartley HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Hartley**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Hartley HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Hartley HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Hartley**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Hassans Walls to the south-east showing the short vertical sandstone cliff sections and concave talus slopes in the background, with the lower colluvial slopes and plains of the Hartley HGL in the foreground (Photo: DECCW/Neville Pavan).

Photo 2: View from Mount Victoria to the north-west showing the short vertical sandstone cliff section and concave talus slopes of the Hartley HGL (Photo: DECCW/Neville Pavan).

Photo 3: View from Mount York to the north-west showing the lower colluvial slopes and plains of the Hartley HGL (Photo: DECCW/Neville Pavan).

Photo 4: View from the Vale of Clywwd Road to the east showing the long low-gradient colluvial slopes of the Hartley HGL (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Hartley HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale (Blue Mountains Plateau). Illawarra Group– carbonaceous shale, grey shale, thick coal seams (Hartley Valley). Shoalhaven Group (Berry Siltstone) – sandy grey mudstone, minor siltstone, lithic sandstone, conglomerate (Hartley Valley). Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited on the floodplains of streams that pass through.
Annual Rainfall	800–900 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep (32–55%) to precipitous sandstone mountain escarpments (>220 m), in the upper part of the landscape, with rises (10–30 m), colluvial slopes and narrow alluvial plains in the lower parts of the landscape. This unit is present at altitudes between 560 m and 1041 m with gently inclined slopes 0% to 10% lower in the landscape, and rock outcrop typically <2%. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes from highest to lowest elevation are represented by Wollangambe (wox) Hassans Walls (hwz), Cullen Bullen (cbz), Lithgow (lix) and Pipers Flat (pfz). On crests and upper slopes soil types include Rudosols (Siliceous Sands/Lithosols) and Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). On midslopes typical soil types are Yellow and Brown Kandosols (Yellow and Brown Earths) and Kurosols (Yellow, Red and Brown Podzolic Soils). Drainage lines contain Kurosols and Sodosols (Yellow Podzolic Soils, Solodised Solonetz). Streams and rivers characteristically have Tenosols (Grey-Brown Alluvial Soils) and Kurosols (Yellow Podzolic Soils and Soloths). Soils are generally infertile and prone to degradation. They are sodic and readily disperse on lower slopes and in minor drainage lines. Moderate gully erosion is evident along some drainage depressions. Minor sheet erosion is common where ground cover has been disturbed by clearing. Extensive severe sheet and rill erosion have occurred on isolated steeper slopes. Severe stream bank erosion along streams and rivers.
Rural and Urban Land Capability *(Emery 1986)*	• Rural: Typically Class VIII for the cliff sections, Classes VII and VI for the timbered foothills, and Class IV on the colluvial slopes with localised areas of Class V • Urban: B (C).

Land Use	The Hartley HGL has a high incidence of rural residential land use. Elsewhere land is largely freehold with grazing on native and modified pastures on colluvial slopes. Remnants of coal and shale mines are distributed throughout. Native forest on steeper areas.
Key Land Degradation Issues	**Limitations:** Steep slopes - Sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded. Rock fall on cliffs. Sheet and rill erosion (talus areas). Minor gully erosion (colluvial slopes). Waterlogging (<1 ha).
Native Vegetation *(Keith 2004; DEC 2006; Tozer et al. 2010)*	The distinguishing signature of Hartley HGL vegetation is the *Tableland Grassy Box-Gum Woodland* (DEC 2006) which, in the Lithgow area, is strictly within Hartley HGL, occurring ubiquitously on the lower slopes and flat areas (MA5) of the HGL. The Hartley HGL has a similar vegetation transect to Angus Place HGL with similar landforms and geology. The vegetation on flat ridges and pagoda landscapes (MA1) in the Hartley HGL is typically Heathlands and Dry Sclerophyll Forest communities (Keith 2004), similar to Angus Place HGL and Hassans Walls HGL, grading into Dry Sclerophyll Forests with occasional pockets of Rainforest and Wet Sclerophyll Forest (Keith 2004) on upper talus slopes (MA2/3). The distinguishing Grassy Woodland community of *Tableland Grassy Box-Gum Woodland* dominates on lower slopes (MA5) and a combination of Grassy Woodlands, Wetlands and Wet Sclerophyll Forests (Keith 2004) occur within the riparian zone (MA10). The riparian zone supports the Endangered Ecological Community of *Montane Peatlands and Swamps* (NSW SC 2004) and includes areas of the nationally endangered community of *Temperate Highland Peat Swamps on Sandstone* (TSSC 2005). ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Hartley HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	High. Range: >10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate to high. Range: 5–>15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: 15–20 m.
Typical Catchment Size	Medium (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when determining appropriate management actions. Short and long-term climate cycles also must be considered as they influence salinity processes, particularly salt load and land salinity.

Landscape Function – Hartley HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source

- This landscape provides fresh water runoff as an important dilutions flow source
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Hartley HGL

Appropriate overall strategies pertinent to this landscape:

Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Hartley HGL

Focus is on vegetation management in the upper landscape and grazing management on the valley floor.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchment's salinity contribution
- There are significant areas of native pastures and remnant vegetation left in this landscape to act as a seed source and basis for sound native pasture and remnant vegetation management
- This HGL has local systems with recharge and discharge commonly on the same farm (short flow paths <10km)
- Little salt store that comes in contact with fresh water.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Steep slopes limit land use opportunities mainly due to high level of vegetation in the catchment
- Limited capability for high density urban development
- Pressure of small subdivision development
- Colluvial areas which are wet for long periods in winter, retard plant growth
- Cool climate a seasonal impediment to plant growth.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

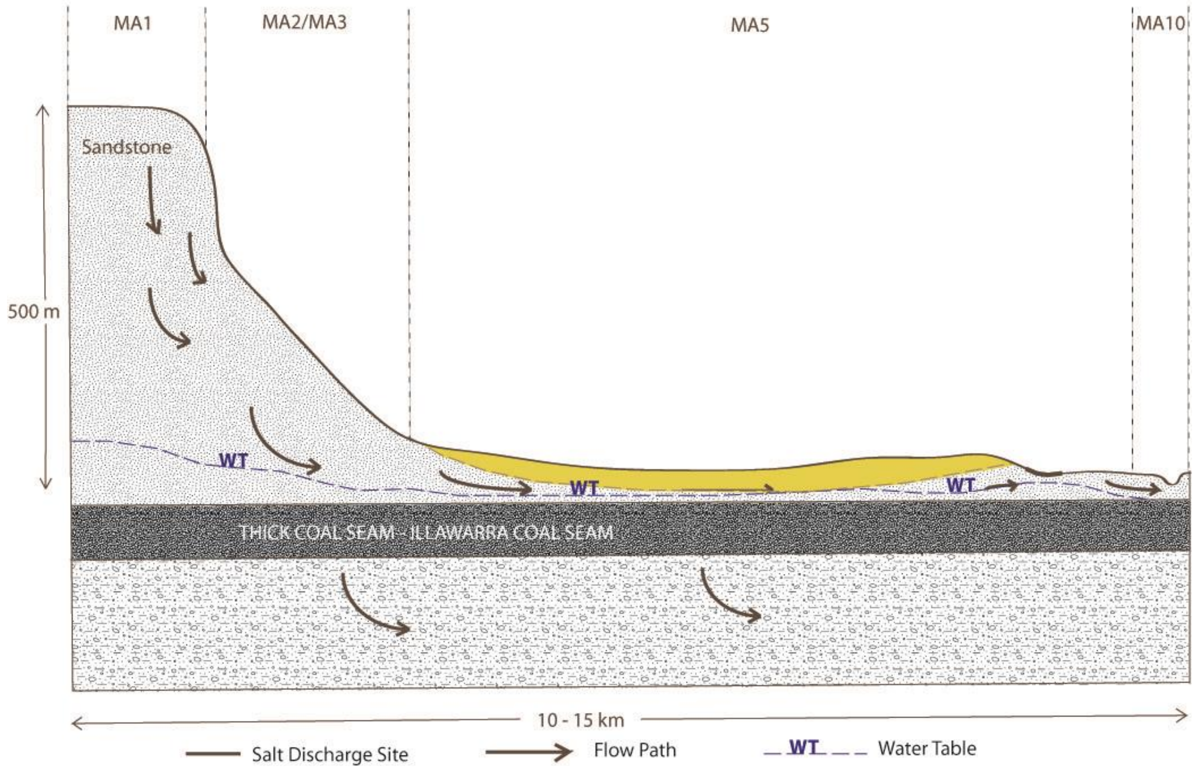


Figure 3: Management cross-section for Hartley HGL showing defined management areas.

Table 6: Specific management actions for management areas within Hartley HGL.

Management Area (MA)	Action
MA1 (Cliffs and escarpments)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) Steep timbered slopes **MA3** (Upper slopes – colluvial) Talus slope	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5).
MA5 (Lower slopes – colluvial) Long colluvial slope	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Salt land rehabilitation**

Management Area (MA)	Action
	Establish and manage salt land pasture for productive use of salt land (if salt outbreaks become present) (SR2).
MA7 Discharge site – saline) Minor salt sites in waterlogged areas	**Minor salt sites in waterlogged areas** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Hartley HGL.

At Risk Management Areas	Action
MA5	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).
MA5	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2,	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce vegetation water use and increase rates of recharge (DLU4).

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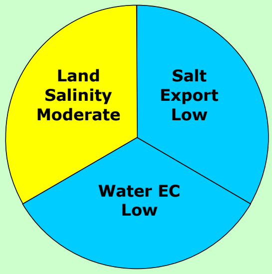
2. Angus Place Hydrogeological Landscape

LOCALITIES	**Angus Place**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Angus Place Hydrogeological Landscape (HGL) is located on the eastern edge of Upper Coxs River valley north of Lithgow. The area receives >900 mm of rain per annum.

The landscape is distinguished by having a pagoda landscape in the upper elements and a wetland (swamp) is commonly located along the central drainage line on the valley floor, but in places the drainage is incised.

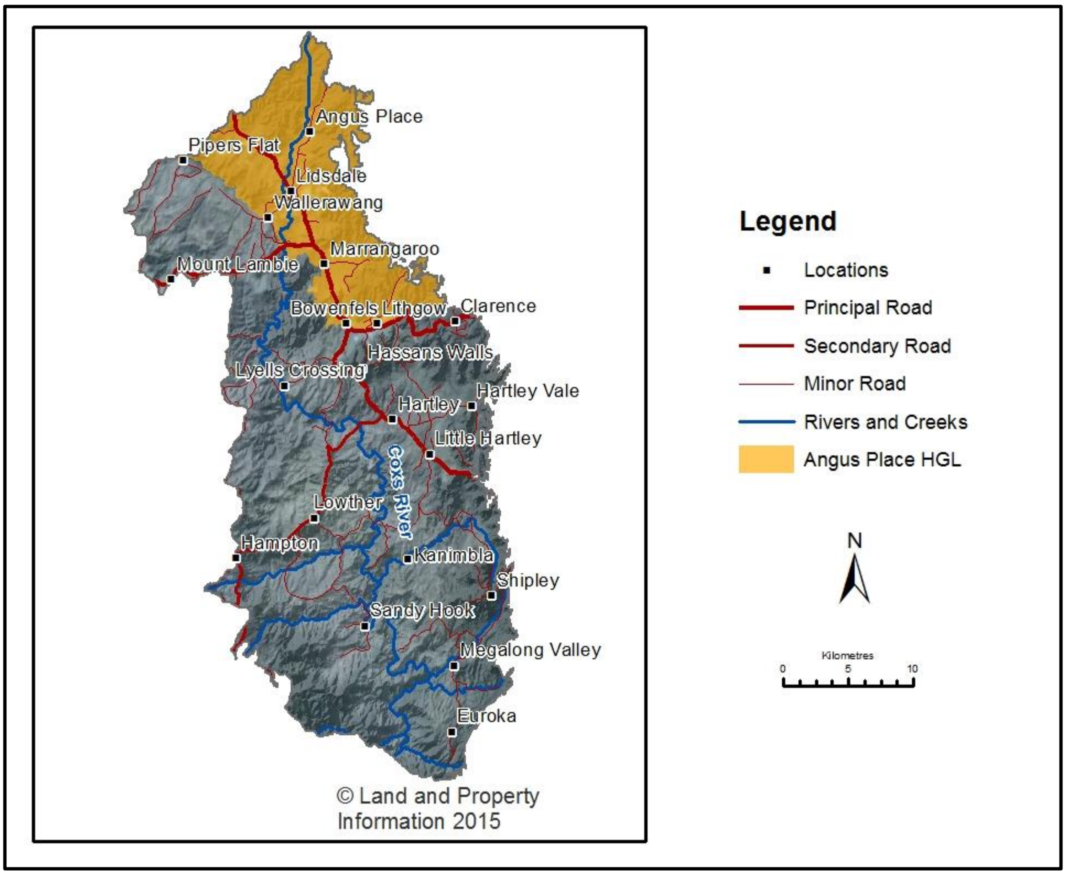


Figure 1: Angus Place HGL location map.

Angus Place HGL is characterised by flat-lying Permo-Triassic sandstone-quartz, sandstone-lithic, ironstone and conglomerate within the Upper Coxs River valley. The landscape features sandstone pagodas, a talus slope, rolling rises with lower colluvial and alluvial areas adjacent to swampy drainage lines (e.g. Long Swamp). Typical lithologies for this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and major coal seams of the Illawarra Group; and siltstone, sandstone and conglomerate of the Shoalhaven Group. This landscape features resistant Narrabeen Sandstones forming a pagoda landscape, local relief (90–130 m) and mountains (900–1184 m) above a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope. Lower in the landscape are rolling rises adjacent to relatively flat alluvial plains and swamps.

Water infiltrates through the pagoda landscape and plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Some of this groundwater will move laterally across bedding in the Illawarra Group, low in the stratigraphy, below ground level. Salt may mobilise at that level however it is not expressed at the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Lower in the landscape water moves laterally through the colluvial materials, and may emerge in the drainage lines as swamps.

This HGL has small (<1 ha) waterlogged sites that form adjacent to the swamps. Occasionally on low rises where there is a texture contrast and a slope change there may be rare small seasonal saline scalds. There is limited to moderate expression of salt in this HGL and a corresponding low salt load to streams and low EC values.

Grazing of beef cattle on native and modified pasture on freehold land is the most widespread land use. Smaller areas are devoted to state forests, coal mining, power stations, shale quarries and residential urban use (Lithgow, Marrangaroo, Wallerawang and Lidsdale). Elsewhere woodland vegetation remains on the pagodas, short cliffs and talus slopes.

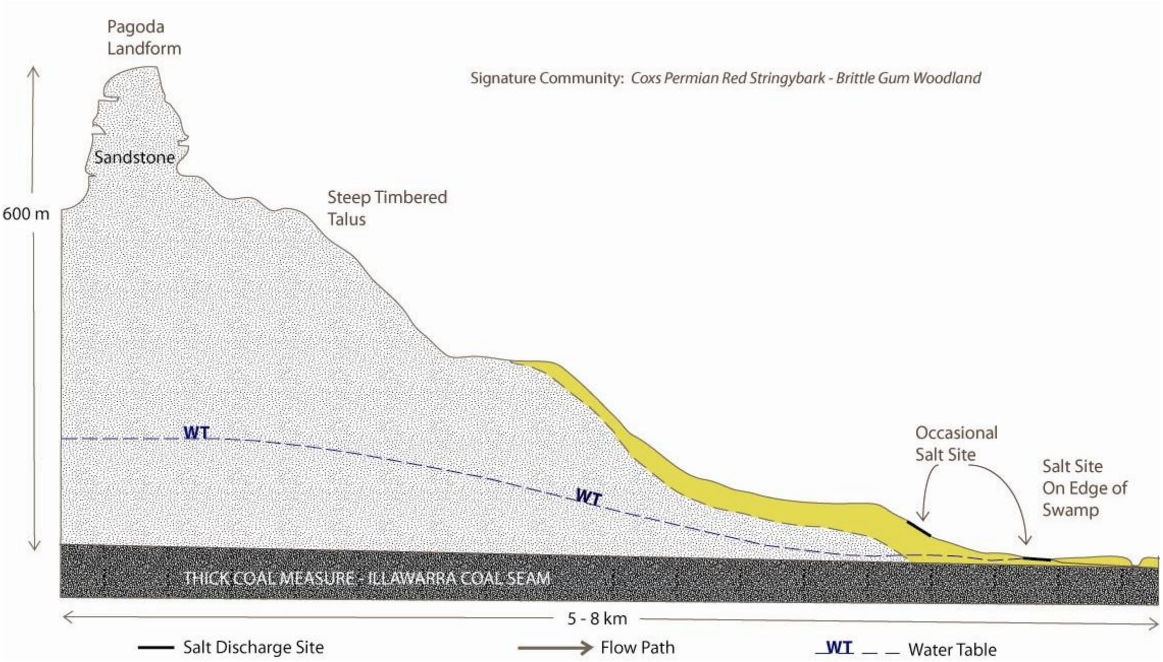


Figure 2: Conceptual cross-section for Angus Place HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Angus Place HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Rare small seasonal saline scalds may be adjacent to wetlands.
Salt Load (Export)	Low salt store in this landscape. Salt store is likely to be deeper in the profile and immediately below ground level. Mobilisation of salt may occur at that level however does not express at the land surface. Relatively fresh water.
EC (Water Quality)	High quality relatively fresh water (<0.2 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Angus Place HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Angus Place HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Angus Place**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Angus Place HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Angus Place HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Angus Place**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Springvale Road to the north-east showing rolling rises adjacent to alluvial areas in the foreground, and a convex talus slope rising to a vertical pagoda at the top of a short sandstone cliff section of the Angus Place HGL in the background (Photo: DECCW/Neville Pavan).

Photo 2: View from Wolgan Road to the east showing rolling rises of the lower colluvial slopes, rising to the talus slope and pagoda escarpment features of the Angus Place HGL (Photo: DECCW/Neville Pavan).

Photo 3: View from Wolgan Road to the east showing rock pagoda outcrops at the top of the short sandstone cliff section of the Angus Place HGL. These structures are a special feature of this HGL (Photo: DECCW/Neville Pavan).

Photo 4: View from Wolgan Road to the east showing the rolling rises of the lower colluvial slopes of the Angus Place HGL in the foreground (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Angus Place HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale (Blue Mountains Plateau and Pagodas) • Illawarra Group – carbonaceous shale, grey shale, thick coal seams (Coxs River) • Shoalhaven Group (Berry Siltstone) – sandy grey mudstone; minor siltstone, lithic sandstone, conglomerate (Coxs River). Unconsolidated alluvial sediments derived from the surrounding Permian and Triassic sedimentary rocks have been deposited on the floodplains of streams that pass through and in swampy areas on the valley floor.
Annual Rainfall	800–900 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep (32–55%) to precipitous sandstone pagodas (>200 m) in the upper part of the landscape, with hills (90-130 m), low hills (30-90 m) rises (9–30 m) and alluvial plains (<9 m) in the lower parts of the landscape. This unit is present at altitudes between 900 m and 1184 m, with steep to precipitous slopes (30–100%) and rock outcrop typically >50%. Regolith materials are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands in the upper parts of the landscape and lithic gravelly sands and sandy clays on colluvial slopes.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes from highest to lowest elevation are represented by Wollangambe (wox) or Mount Sinai (msz), Hassans Walls (hwz), Cullen Bullen (cbz), Lithgow (lix), Pipers Flat (pfz) and Long Swamp (lsz). Pagoda rock formations are characteristic of Mount Sinai Soil Landscape (msz) which distinguishes this landscape from Wollangambe. On crests and upper slopes soil types include Rudosols (Siliceous Sands/Lithosols) and Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). On midslopes typical soil types are Yellow and Brown Kandosols (Yellow and Brown Earths) and Kurosols (Yellow, Red and Brown Podzolic Soils). Drainage lines contain Kurosols and Sodosols (Yellow Podzolic Soils, Solodised Solonetz). Streams and rivers characteristically have Tenosols (Grey-Brown Alluvial Soils) and Kurosols (Yellow Podzolic Soils and Soloths). Organosols (Peaty Loams) and Hydrosols (Grey Earths, Humic Gleys) are found in swamps. The sodic soils are generally infertile. They readily disperse on lower slopes and in minor drainage lines. Moderate gully erosion is evident along some drainage depressions. Minor sheet erosion is common where ground cover has been disturbed by clearing.
Rural and Urban Land Capability *(Emery 1986)*	Rural: Typically Class VIII for the cliff and pagoda sections, Classes VII and VI for the timbered foothills, and Class IV and Class V on the alluvial areas. Urban: B (C).

Land Use	The ridges and pagodas lie within the Blue Mountains National Park. Smaller areas are found within the Newnes State Forest. The landscape remains largely undeveloped. Grazing of beef cattle on freehold land is the most widespread land use on the colluvial slopes. Smaller areas are devoted to state forests, coal mining, power stations, and residential urban use (Lithgow, Marrangaroo, Wallerawang, Cullen Bullen). Coal mines are distributed throughout the landscape. There is native forest on steeper areas.
Key Land Degradation Issues	Limitations: • Steep slopes – sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded • Rock fall on cliffs • Sheet and rill erosion (talus areas) • Minor gully erosion (colluvial slopes) • Waterlogging (<1 ha) • Previously disturbed land.
Native Vegetation *(Keith 2004; DEC 2006; Tozer et al. 2010)*	The specific signature of *Coxs Permian Red Stringybark – Brittle Gum Woodland* (DEC 2006) is unique to the Angus Place HGL, occurring on talus slopes (MA3). The HGL predominantly supports Dry Sclerophyll Forest (Keith 2004) communities throughout. In addition, it has a ubiquitous suite of open forest to woodland and low heath communities reflecting the dry, exposed sandy landscapes and often shallow soils with rocky outcrops. In drainage lines, gullies and in swampy areas along the Coxs River (e.g. Long Swamp) the vegetation communities are taller forests or Freshwater Wetlands (Keith 2004), including the Endangered Ecological Community of *Montane Peatlands and Swamps* (NSW SC 2004). Wet Sclerophyll Forests (Keith 2004) form on the eastern boundary of the HGL, signifying a change in landscape into the adjacent Hawkesbury Sandstone HGL, i.e. on the edge of Newnes State Forest. As these Wet Sclerophyll Forests are not an identifying feature of this HGL they are not profiled here. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Angus Place HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and plains.
Hydraulic Conductivity	High. Range: >10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate to high. Range: 5–>15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Intermediate to deep. Range: 5–20 m.
Typical Catchment Size	Medium (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Short to medium (months to years)
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Angus Place HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Angus Place HGL

Appropriate overall strategies pertinent to this landscape:

- **Maintaining and maximising runoff (10):** This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Angus Place HGL

The focus is to maintain the remnant vegetation across this landscape, and in the lower areas manage grazing in cleared landscape. Long Swamp requires flow management to maintain integrity. There are some mine restoration works in the area.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchment's salinity contribution
- There are significant areas of native pastures and remnant vegetation left in this landscape as a seed source and basis for sound native pasture and remnant vegetation management
- This HGL has local systems with recharge and discharge commonly on the same farm (short flow paths <10 km)
- Escarpment and swamp biodiversity outcomes
- Little salt store that comes into contact with fresh water.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Steep slopes limit land use opportunities mainly due to high level of vegetation in the catchment
- Limited capability for agricultural and urban development
- Pressure of rural residential subdivision development
- Pressure of mining development.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

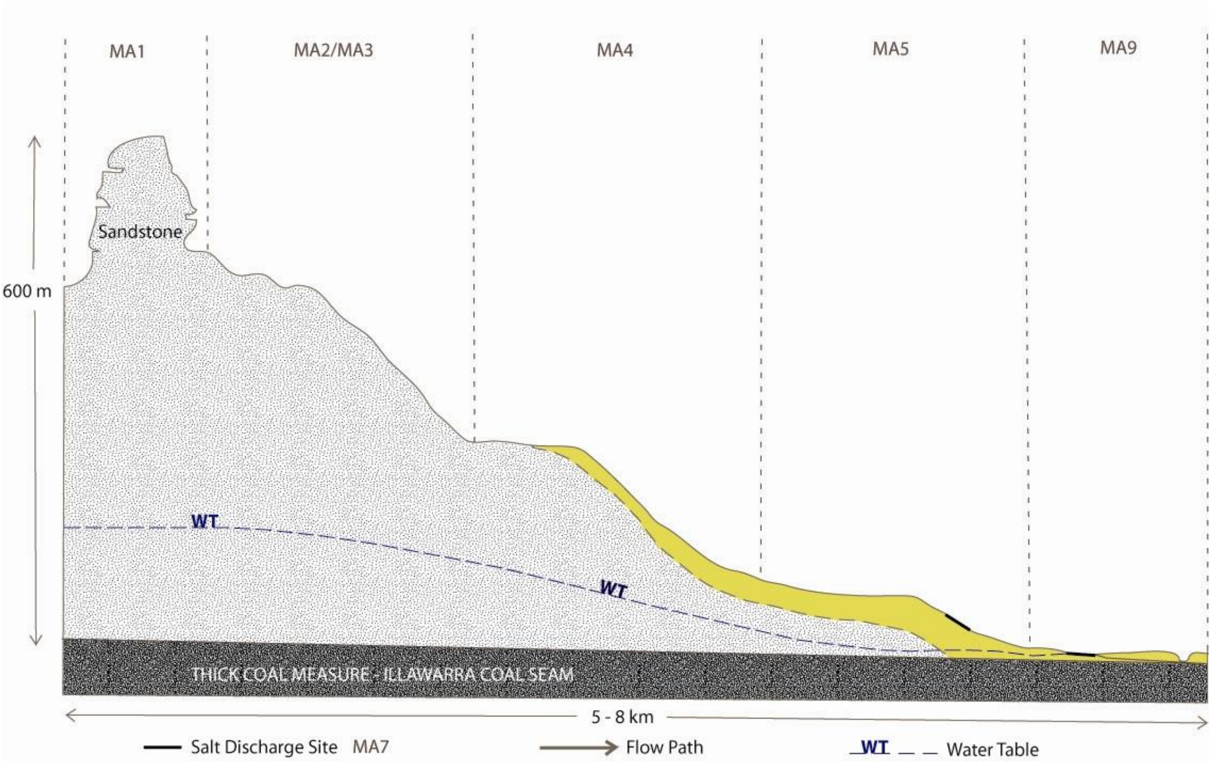


Figure 3: Management cross-section for Angus Place HGL showing defined management areas.

Table 6: Specific management actions for management areas within Angus Place HGL.

Management Area (MA)	Action
MA1 (Pagoda)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) – steep timbered slopes **MA3** (Upper slopes – colluvial) – talus slope	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA5 (Lower slopes – colluvial) Long colluvial slope	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service**

Management Area (MA)	Action
	Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA7 (Discharge site – saline) Minor salt sites in waterlogged areas	**Minor salt sites in waterlogged areas** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).
MA9 (Alluvial plain)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Angus Place HGL.

At Risk Management Areas	Action
MA4, MA5, MA9	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).
MA4, MA5, MA9	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2, MA3	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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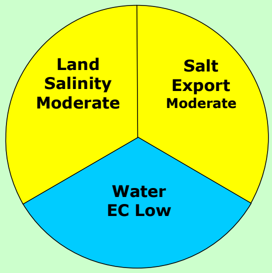
3. Pipers Flat Hydrogeological Landscape

LOCALITIES	**Pipers Flat, Mount Lambie, Thompsons Creek**
GEOLOGY SHEET	**Sydney 1:250 000** **Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Pipers Flat Hydrogeological Landscape (HGL) is located to the north-west of Lithgow, in the Upper Coxs River valley. The area receives >850 mm of rain per annum.

Pipers Flat HGL can be distinguished from adjacent HGLs because it has localised granite outcrops within a shaly rock sequence in the upper parts of the landscape, and a more open rolling landscape than those dominated by Narrabeen sandstone cliff sections.

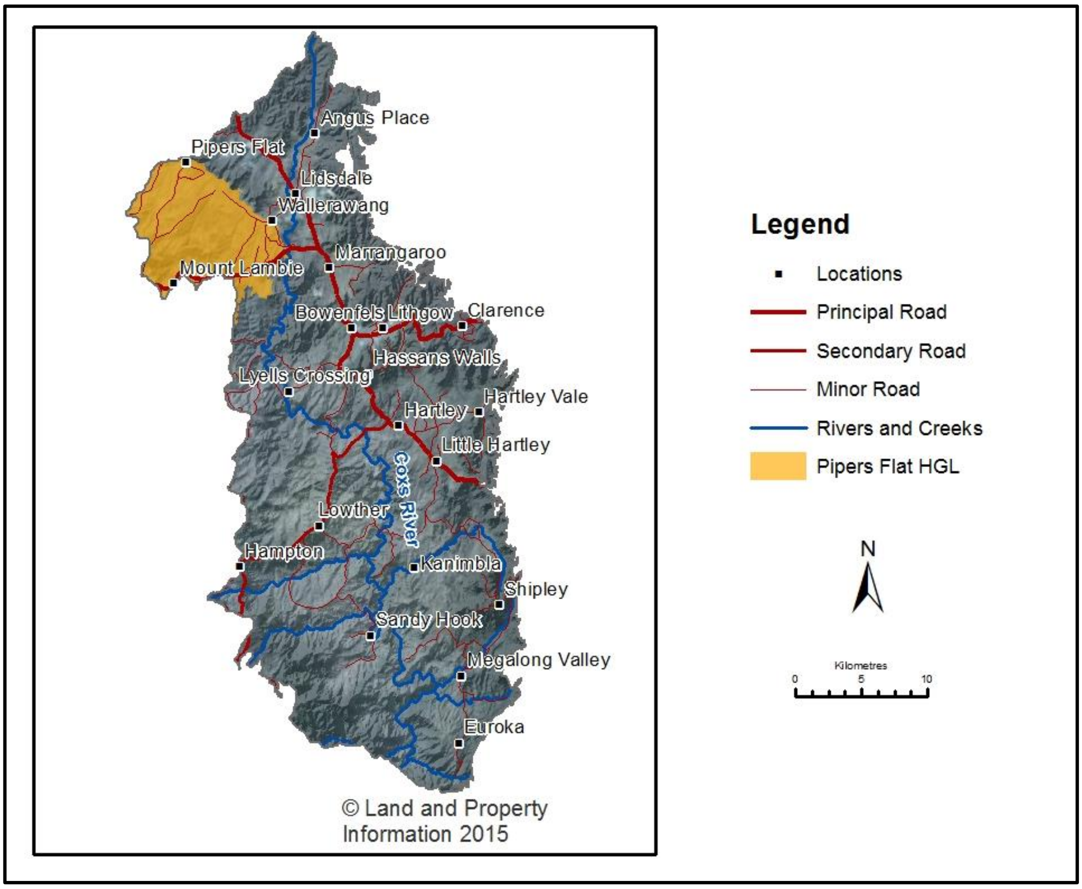


Figure 1: Pipers Flat HGL location map.

The Pipers Flat HGL is characterised by flat-lying Permo-Triassic Shoalhaven Group sandstone, siltstone and conglomerate within the Upper Coxs River Valley. The landscape features localised outcrops of Carboniferous granite and Silurian slate, shale, siltstone of the

Chesleigh Group in the upper landscape, and rolling rises on lower colluvial and alluvial areas adjacent to swampy drainage lines (e.g. Pipers Flat Creek). Typical lithologies for this HGL are moderately weathered granites, with exposed boulders a feature on upper-slopes, and moderately weathered felsic volcanic sediments, on upper and lower slopes. There are younger (Permo-Triassic) units in the lower parts of the landscape represented by sandstone, siltstone shale, claystone and coal seams of the Illawarra Group, and siltstone, sandstone and conglomerate of the Shoalhaven Group (Berry Formation). Recent alluvium (unconsolidated sands and gravels) overlie these rocks on the valley floor.

Local surface water catchments are small (100 ha to 500 ha). Recharge to the groundwater system (both deep and shallow) occurs across the HGL. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material, and at contacts between rock types, until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Some of this groundwater will move laterally across bedding in the Illawarra and Shoalhaven Groups low in the stratigraphy, below ground level. Salt may mobilise at that level however it is not expressed at the land surface. Lower in the landscape water moves laterally through the colluvial materials, and may emerge in the broad drainage lines.

There is limited to moderate expression of salt in this HGL and a corresponding low to moderate salt load to streams, but EC values are generally low. Small sites (<1 ha) may exist where impediments to drainage occur near infrastructure, e.g. roads, and where water emerges at texture contrasts on the lower slopes and in the broad alluvial channels.

Grazing of sheep and beef cattle on native and modified pasture on freehold land is the most widespread land use. Smaller areas are devoted to state forests, and some residential urban use (Wallerawang).

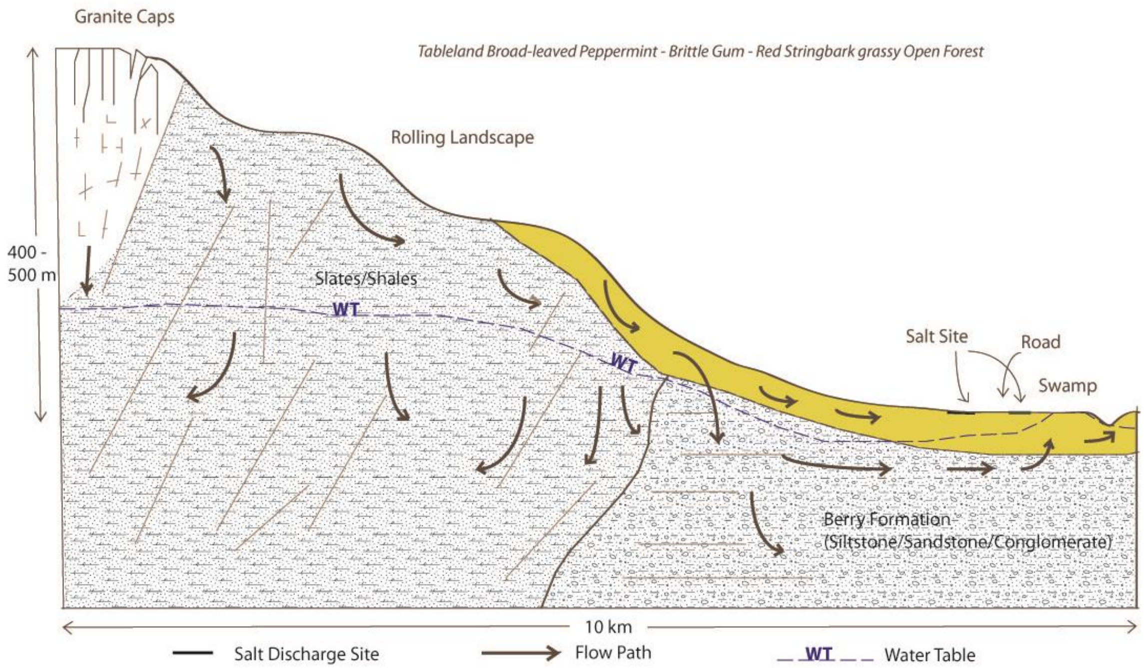


Figure 2: Conceptual cross-section for Pipers Flat HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Pipers Flat HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Small seasonal saline scalds may be present adjacent to wetlands in areas of impeded drainage (e.g. roads).
Salt Load (Export)	A low salt store exists in the upper landscape. Salt store is likely to be greater in the mid-slope areas and below ground level. Salt sites can exist on the lower colluvial slopes.
EC (Water Quality)	High quality relatively fresh water (<0.2 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Pipers Flat HGL has moderate mobility. There is a moderate salt store that has moderate availability (Table 2).

Table 2: Pipers Flat HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store		**Pipers Flat**	
Low salt store			

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Pipers Flat HGL is moderate. This is due to the moderate likelihood that salinity issues will occur and that they would have potentially significant impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Pipers Flat HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence		**Pipers Flat**	
Low likelihood of occurrence			

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Range Road to the north-east showing rolling rises adjacent to colluvial areas of the Pipers Flat HGL, near Portland Road (Photo: DECCW/Neville Pavan).

Photo 2: View from Range Road to the north-east showing rolling rises of the Pipers Flat HGL (Photo: DECCW/Neville Pavan).

Photo 3: View from Range Road to the north-east showing rolling rises and colluvial slopes of the Pipers Flat HGL, near Portland Road (Photo: DECCW/Neville Pavan).

Photo 4: View from Range Road to the north-east showing rolling rises of the Pipers Flat HGL, in a rural residential setting (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Pipers Flat HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises extrusive volcanic rocks and associated sediments from the Silurian period, intrusive granitic rocks from the Carboniferous period, and consolidated sedimentary rocks from the Permian period. Key lithologies include: • Shoalhaven Group (Berry Siltstone) – sandy grey mudstone; minor siltstone, lithic sandstone, conglomerate • Tarana Granite (eastern expression) – coarse-grained, porphyritic biotite granite, porphyritic granite and granodiorite with aplite • Chesleigh Group – felsic volcaniclastic, quartz-lithic, feldspar-lithic and quartzose sandstone, siltstone, slate, shale; crystal and vitric tuff; breccia and conglomerate; chert, felsic porphyry. Unconsolidated colluvial and alluvial sediments derived from the surrounding rocks have been deposited on lower slopes and along streams that pass through.
Annual Rainfall	850 mm.
Regolith and Landforms	This HGL is variably weathered but is characterised by moderately weathered granite and felsic volcanic rocks forming low hills (20–50 m). Localised areas of low tors (<1.5 m) and subcrop are present on ridges and on midslope bedrock highs. A layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven Group, is present in the lower parts of the landscape forming rises (30–90 m) and plains. This unit is present between 533 m and 1128 m ASL; with gently inclined to inclined slopes (10–25%), and rock outcrop typically <2%. Regolith materials are dominantly quartzose coarse sandy kaolinite-bearing clays and clayey sands and gravels on the crests. There are quartzose, lithic clayey sands and sandy clays on colluvial slopes and unconsolidated sands and gravels form the alluvium.
Soil Landscapes *(DECC 2008; OEH 2017)*	This HGL is represented by part of the Bathurst (ba) and Cullen Bullen (cb) Soil Landscapes. The Pipers Flat HGL consists of gently undulating rises to rolling hills with mainly Yellow Podzolic Soils and Yellow Earths (Yellow Kurosols and Kandosols), Non-Calcic Brown Soils on crests and upper slopes, Yellow Podzolic Soils and Solodised Solonetz (Kurosols and Sodosols) on midslopes, and Grey-Brown Alluvial Soils (Tenosols), Yellow Podzolic Soils, Soloths (Kurosols), and Yellow Solodic Soils on lower slopes and in depressions.
Rural Land Capability *(Emery 1986)*	Typically Class IV on mid and lower slopes, and Class V where bedrock is exposed.
Land Use	Mostly freehold land used for grazing of sheep, beef cattle and horses on both modified and native pastures.
Key Land Degradation Issues	**Limitations:** • Steep slopes - Sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded • Gully erosion - <1.5 m deep is evident throughout the landscape particularly along most drainage lines. Severe

	stream bank erosion is common on drainage lines. Moderate gully erosion is evident along some drainage lines.
Native Vegetation *(Keith 2004; DEC 2006)*	The most common vegetation signature is of *Tableland Broad-Leaved Peppermint – Brittle Gum – Red Stringybark Grassy Open Forest* (DEC 2006) across the rolling rises, lower colluvial areas (MA5) and alluvial areas adjacent to swampy drainage lines (MA9) of the HGL. Other communities from the Southern Tablelands Dry Sclerophyll Forests state wide community are present across the rolling landforms. The HGL has been extensively cleared and pine plantations exist in the south. Where native vegetation remains in continuous stands or as remnant trees, the HGL predominantly supports Dry Sclerophyll Forest (Keith 2004) communities. All vegetation communities, apart from some riparian vegetation, fall within the Southern Tablelands Dry Sclerophyll Forests vegetation class (Keith 2004). ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Pipers Flat HGL.

Aquifer Type	Unconfined in fractured granites and felsic volcanics. Lateral flow through unconsolidated colluvial and alluvial sediments on slopes and valley floors.
Hydraulic Conductivity	Moderate. Range: 10^{-2}–10 m/day.
Aquifer Transmissivity	Low to moderate. Range: <2–100 m^2/day.
Specific Yield	Low to moderate. Range: <5 –15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Intermediate to deep. Range: 5–20 m.
Typical Catchment Size	Medium (100–500 ha).
Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	Moderate to high.
Residence Time	Short to medium (months to years).

Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Pipers Flat HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source.

Landscape Management Strategies – Pipers Flat HGL

Appropriate overall strategies pertinent to this landscape:

- Maintaining and maximising runoff: This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- Dry out the landscape with diffuse actions over most of the landscape: Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Pipers Flat HGL

Focus in this rolling landscape is to manage the area by vegetation management. There are good stands of native vegetation, and introduced perennials, although soils can limit pasture performance. Grazing management is the key in the area, but there is pressure from small subdivision.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchment’s salinity contribution
- There are significant areas of native pastures and remnant vegetation left in this landscape as a seed source and basis for sound native pasture and remnant vegetation management.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Exposure of Berry Formation layer in upper profiles could lead to significant mobilisation of acid sulphate and highly saline salts
- Limited capability for agricultural and urban development
- Soil limitations – low fertility, high erosion hazard and minor sodicity
- Pressure of rural residential subdivision development.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

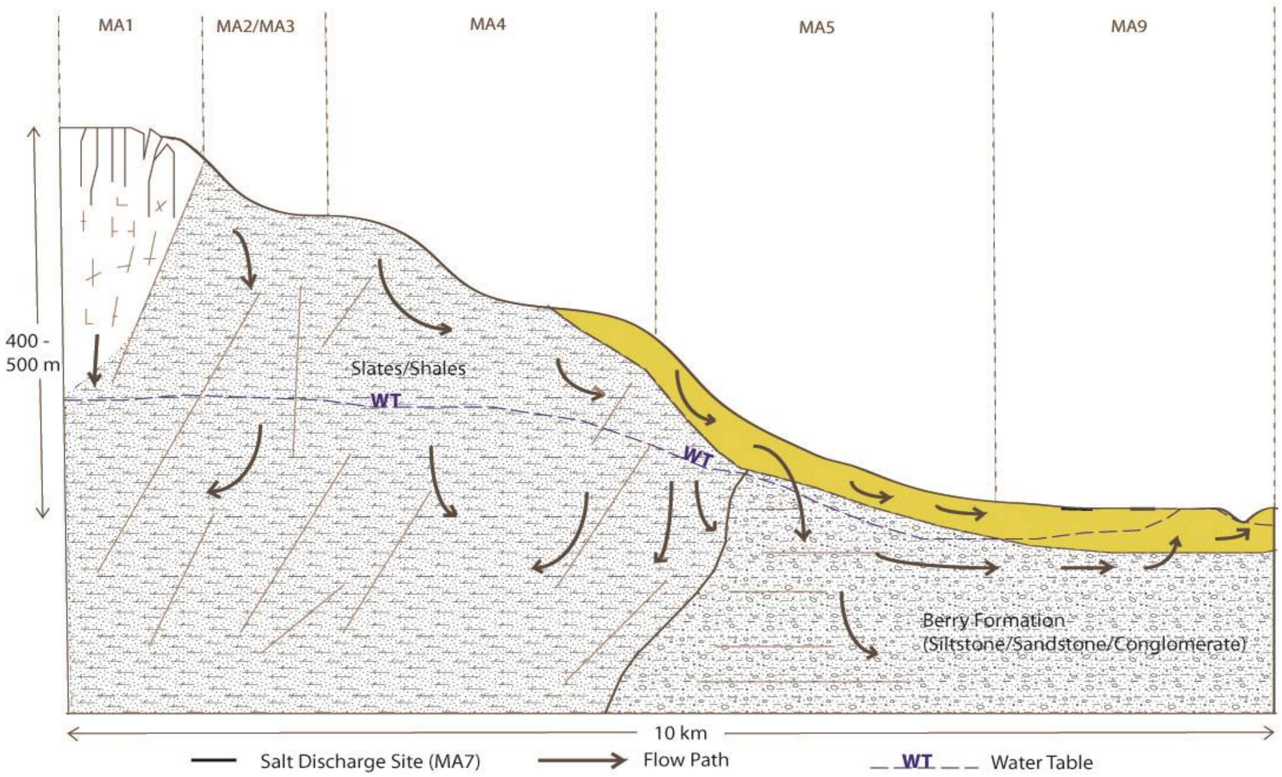


Figure 3: Management cross-section for Pipers Flat HGL showing defined management areas.

Table 6: Specific management actions for management areas within Pipers Flat HGL.

Management Area (MA)	Action
MA1 (Ridges) **MA6** (Rolling rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA3 and **MA2** (Upper slopes – erosional and colluvial) – erosional and colluvium areas	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA5 (Lower slopes – colluvial)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA7 (Discharge site – saline) – minor salt sites in waterlogged areas	**Minor salt sites in waterlogged areas** **Salt land rehabilitation** Establish and manage salt land pasture for productive use of salt land (SR2).

MA9 (Alluvial plain)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Pipers Flat HGL.

At Risk Management Areas	Action
MA4, MA5, MA9	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).
MA4, MA5, MA9	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA1, MA2, MA3, MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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Department of Environment and Climate Change (DECC) 2008, *Soil and Land Resources of the Hawkesbury-Nepean Catchment DVD*, NSW Soil and Land Resources Series, Natural Resources Information Unit, Department of Environment and Climate Change, Parramatta.

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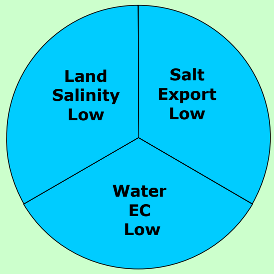
4. Hampton Hydrogeological Landscape

LOCALITIES	**Hampton**
GEOLOGY SHEET	**Sydney 1:250 000** **Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Hampton Hydrogeological Landscape (HGL) is located along the eastern boundary of the Great Dividing Range and lies between Magpie Hollow/Lake Lyell and Beefsteak Creek in the lower Coxs River Valley. The area receives >850 mm of rain per annum.

The upper landscape has Berry Formation sediments, and the remaining landscape is granitic. The Hampton HGL is broadly similar to the Mid Coxs River HGL in geology and landform, the main difference is sandstone on the main ridge crests and steeper slopes draining to the Coxs River.

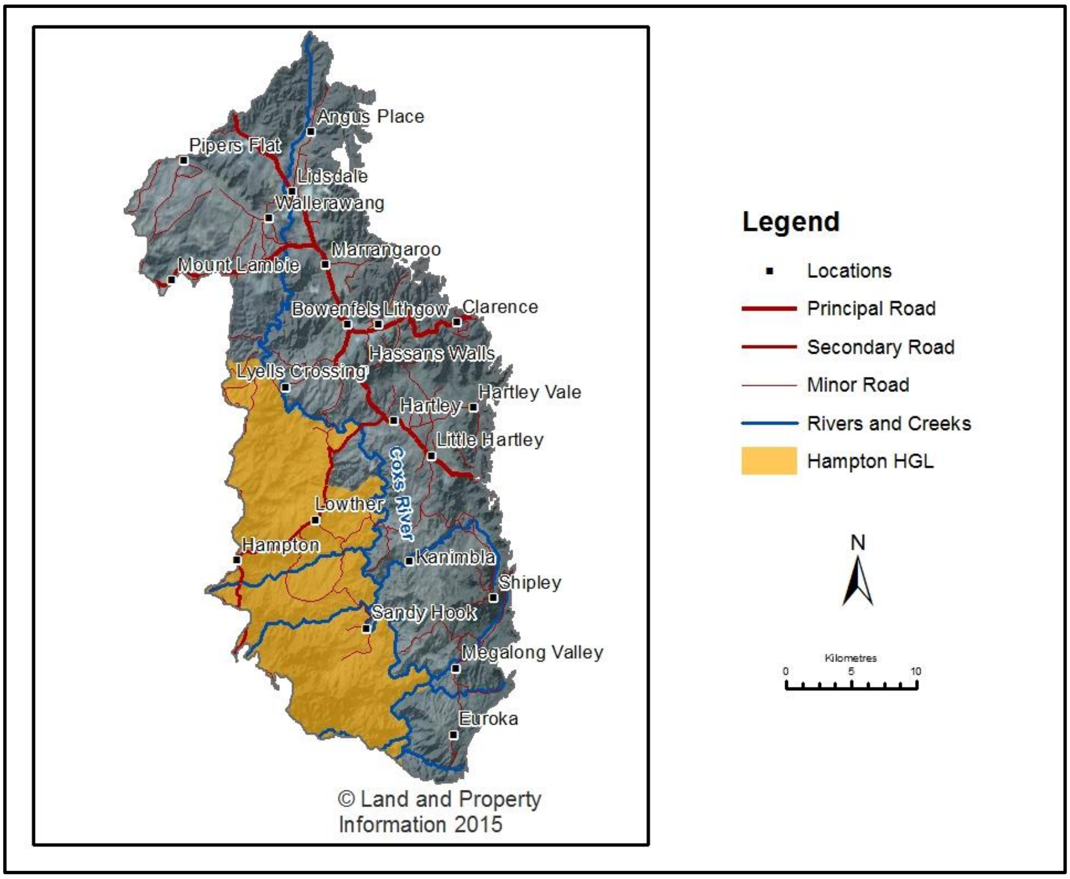


Figure 1: Hampton HGL location map.

The Hampton HGL is characterised by granitic bedrock similar to the landscapes in the Tarana and Fish River areas around Bathurst. The landscape features Berry Formation sandstone, siltstone and conglomerate unconformably overlying Carboniferous granite, forming steep hills, steep slopes and narrow valleys. Typical lithologies for this HGL are moderately weathered medium to coarse sandstone with minor conglomerate and siltstone overlying slightly weathered granite, which locally forms outcrop and subcrop on crests and upper slopes. Moderately inclined upper colluvial slopes consist of coarse sands, gravels and minor clays. Valley floors are generally incised with minor alluvial and colluvial areas of gravels with a sandy matrix. Weathering intensity is low and regolith cover is thin. It features steep mountains, rolling hills, low hills and rises with widespread outcrop and subcrop.

Local surface water catchments are intermediate (<1000 ha) in size. Recharge to the groundwater system (both deep and shallow) is catchment wide, but occurs mainly through the upper slopes, permeable soils and saprolite. Streams are generally ephemeral and receive discharge from groundwater as base flow. There is significant runoff in this HGL.

There is limited salt in the landscape due to moderate slopes, well-drained granitic soil and short flow paths to the river. There may be rare small (<0.5 ha) seasonal saline scalds adjacent to sandstone exposures above the granite. Springs are common in the lower units on this steep, exposed granitic landscape. Interception of water must be carefully considered because the fresh surface runoff dilutes flows to the Coxs River.

Grazing of sheep, horses and beef cattle on native and modified pasture on freehold land is the most widespread land use.

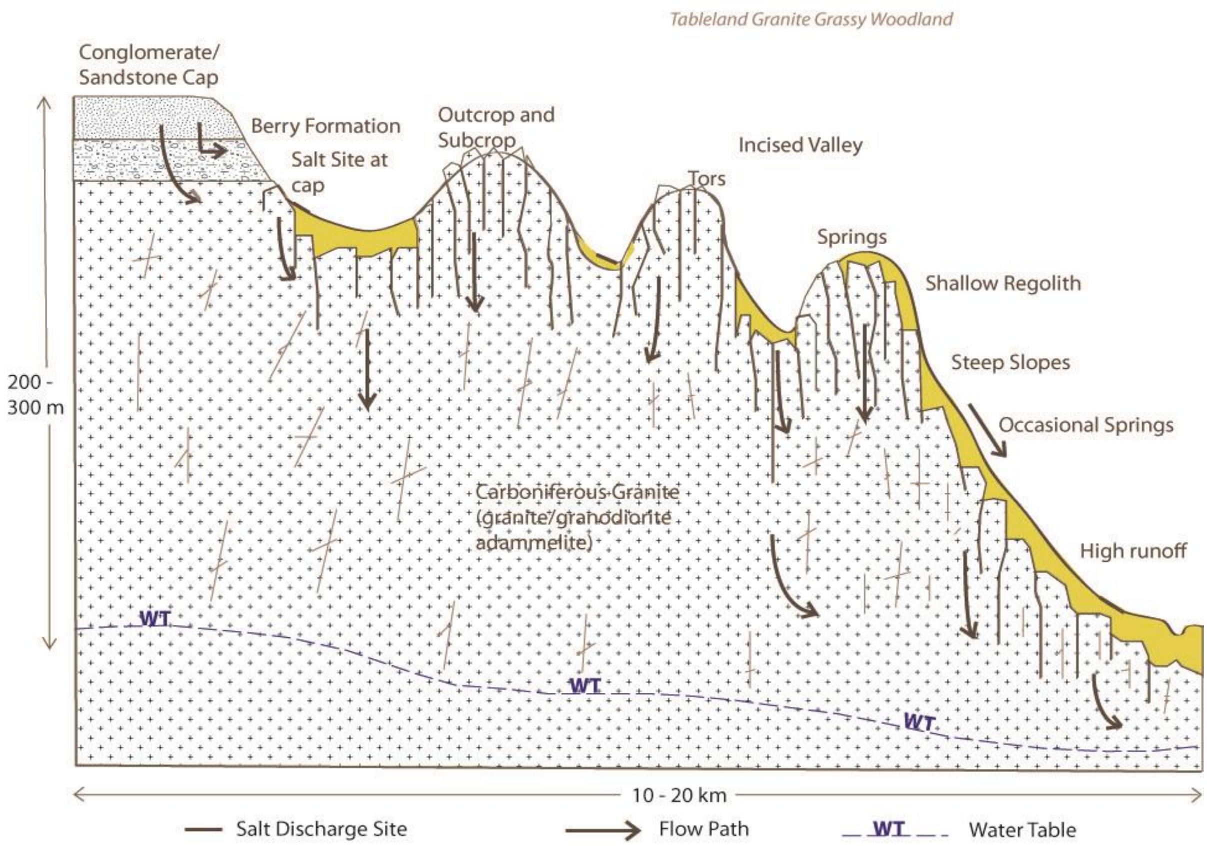


Figure 2: Conceptual cross-section for Hampton HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Hampton HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	Rare small (<0.5 ha) seasonal saline scalds may be adjacent to sandstone exposures.
Salt Load (Export)	A very small salt store exists in the uppermost parts of the landscape. Rare small salt sites may exist on the lower landscape however spring fed flows dilute adverse effects.
EC (Water Quality)	High quality relatively fresh water (<0.2 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Hampton HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Hampton HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Hampton**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Hampton HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Hampton HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Hampton**		

LANDSCAPE ATTRIBUTES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from McKanes Falls Road to the west showing colluvial areas at the foot of steep slopes rising up to the Great Dividing Range, within the Hampton HGL. This is typically a granitic landscape but sandstones are sometimes found at the catchment divide (Photo: DECCW/Neville Pavan).

Photo 2: View from the Hampton/Rydal Road to the east showing the sandstone of the Hampton HGL, present at the catchment divide (Photo: DECCW/Yvonne Preston).

Photo 3: View from the Hampton/Rydal/Tarana Road intersection to the south-east showing the shallow granitic soils of the Hampton HGL, with tors up to 4 m exposed in outcrop and subcrop present in paddocks (Photo: DECCW/Neville Pavan).

Photo 4: View to the east from Hampton/Rydal Road showing low hills with moderate to steep colluvial slopes of the Hampton HGL, with granite subcrop on upper slopes (Photo: DECCW/Yvonne Preston).

Table 4: Summary of information used to define Hampton HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises intrusive granitic rocks from the Carboniferous period, and consolidated sedimentary rocks from the Permian period. Key lithologies include: • Shoalhaven Group (Berry Siltstone) – sandy grey mudstone; minor siltstone, lithic sandstone, conglomerate (Hartley Valley) • Tarana Granite (eastern expression) – coarse-grained, porphyritic biotite granite, porphyritic granite and granodiorite with aplite. Unconsolidated colluvial and alluvial sediments derived from the surrounding rocks have been deposited on lower slopes and along streams that pass through.
Annual Rainfall	850 mm.
Regolith and Landforms	This HGL is variably weathered but is characterised by slightly weathered granite forming mountains (300–500 m), hills (90–300 m) and low hills (30–90 m). Large areas of bedrock are exposed in upper parts of the landscape with outcrops (<4 m) and subcrop. Incised valleys are flanked by steep sides forming lower slopes. This unit is present at altitudes between 110 m and 1262 m; with gently inclined to inclined slopes 2–35%; and rock outcrop typically <10%. Regolith materials are dominantly quartzose coarse sandy kaolinite-bearing clays and clayey sands. Quartzose, lithic clayey sands and sandy clays are found on colluvial slopes and unconsolidated sands and gravels form the alluvium. Regolith cover is typically shallow.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes from highest to lowest elevations are Black Mountain (brz) on conglomerate Marrangaroo (mry) Ben Bullen (bbz), Round Mount (mrz) and Ganbenang (gbz) on granites. Soil types on the conglomerate and sandstone mountain caps include Kandosols (Yellow Earths, Red Earths, Brown Earths and Grey Earths), Kurosols (Yellow Podzolic Soils) and Tenosols (Lithosols and Structured Loams). For the granites that occupy most of this HGL soil types on crests and ridges are Tenosols (Earthy Sands and Lithosols), on midslopes they are Yellow Kurosols (Yellow Podzolic Soils), in drainage lines Tenosols (Siliceous Sands, Earthy Sands) and Yellow Kurosols (Yellow Podzolic Soils) and in swampy depressions Dermosols (Prairie Soils), Kurosols (Yellow Podzolic Soils) and Kandosols (Grey Earths). There is widespread minor sheet and moderate gully erosion. Severe gully erosion along drainage depressions on steeper slopes is locally common. Gully depth is often >1.5 m with the erosion reaching the deep weathering zone (saprolite) of granite bedrock. Severe sheet erosion is common on slopes where tree and ground cover is disturbed.
Rural Land Capability *(Emery 1986)*	Typically Classes VI on upper slopes, IV and V on mid and lower slopes, with Class VII where bedrock is exposed.
Land Use	Mostly freehold land and leasehold land used for grazing of sheep, beef cattle and horses on both modified and native pastures.

Key Land Degradation Issues	**Limitations:** • Steep slopes – sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded • Gully erosion – <4 m deep is evident throughout the landscape particularly along most drainage lines. Severe stream bank erosion is common on drainage lines. Moderate gully erosion is evident along some drainage lines.
Native Vegetation *(Tozer et al. 2010)*	**Signature:** No single vegetation community definitively represents the boundary of the Hampton HGL, however most of the forested hills in Hampton HGL are covered with *Tableland Granite Grassy Woodland* including remnant trees over a majority of the area. **Transect:** The wooded ridge crests in the Hampton HGL support *Tableland Ridge Forest* while most of the colluvial slopes and rises in the landscape have been cleared for agriculture. Remnant paddock trees and continuous stands of native vegetation remain on some steep hills slopes and ridgelines with slopes supporting *Tableland Granite Grassy Woodland* as well as more minor occurrences of *Cool Montane Wet Forest* and the dry sclerophyll forest – *Wollondilly – Cox – Shoalhaven Gorge Woodland.* ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Hampton HGL.

Aquifer Type	Unconfined in fractured rock and saprolite. Lateral flow along underlying contacts and through colluvium on lower slopes.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate. Range: 5 –15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: >20 m.
Typical Catchment Size	Medium (100–1000 ha).
Scale	Local.

(Flow Length)	Flow length: <10 km (short to intermediate).
Recharge Estimate	Moderate to high.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Hampton HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Hampton HGL

Appropriate overall strategies pertinent to this landscape:

- Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Hampton HGL

Focus is maintaining vegetation cover in the upper landscape sediments, and grazing management in the lower granitic slopes which are also prone to erosion.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchment’s salinity contribution
- There are significant areas of native pastures left in this landscape as a seed source and basis for sound native pasture.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Slopes are steep and catchment contributes to dilution flows
- Commercial forestry needs to carefully consider catchment water yield implication
- Pressure of rural residential subdivision development.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

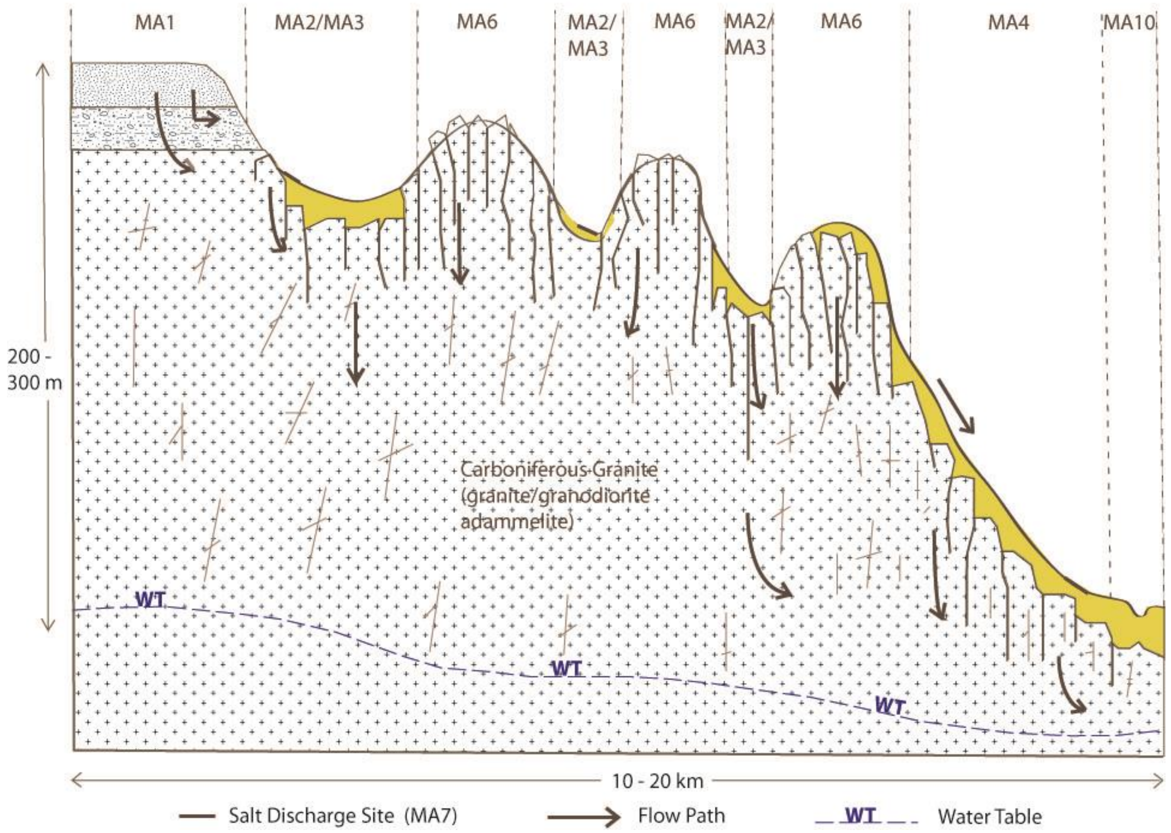


Figure 3: Management cross-section for Hampton HGL showing defined management areas.

Table 6: Specific management actions for management areas within Hampton HGL.

Management Area (MA)	Action
MA1 (Ridges)	**Vegetation for production** Maintain and improve native pastures to manage recharge (VP5). Improve grazing management of existing perennial pastures to manage recharge (VP1). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).

Management Area (MA)	Action
MA3 and **MA2** (Upper slopes – erosional and colluvial) – erosional and colluvium areas	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5).
MA6 (Rolling rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA7 (Discharge site – saline) – minor salt sites under sandstone cap	**Minor salt sites at sandstone contact** **Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Hampton HGL.

At Risk Management Areas	Action
MA2, MA3, MA4, MA6	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6). Commercial plantation forestry. This area provides fresh water to the catchment, and contributes dilution flows (VP7).
MA2, MA3, MA4, MA6	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).

At Risk Management Areas	Action
MA1, MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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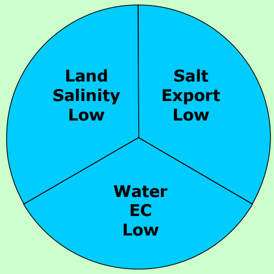
5. Mid Coxs River Hydrogeological Landscape

LOCALITIES	**Mid Coxs River, Hartley, Glenroy, Duddawarra**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Mid Coxs River Hydrogeological Landscape (HGL) is located along the Mid Coxs River Valley between Lithgow and Mount Sandy. The area receives >850 mm of rain per annum.

The Mid Coxs River HGL differs from the Hampton HGL as there is an absence of sandstone on ridge crests and the slopes are less steep. The landscape is a granitic landscape.

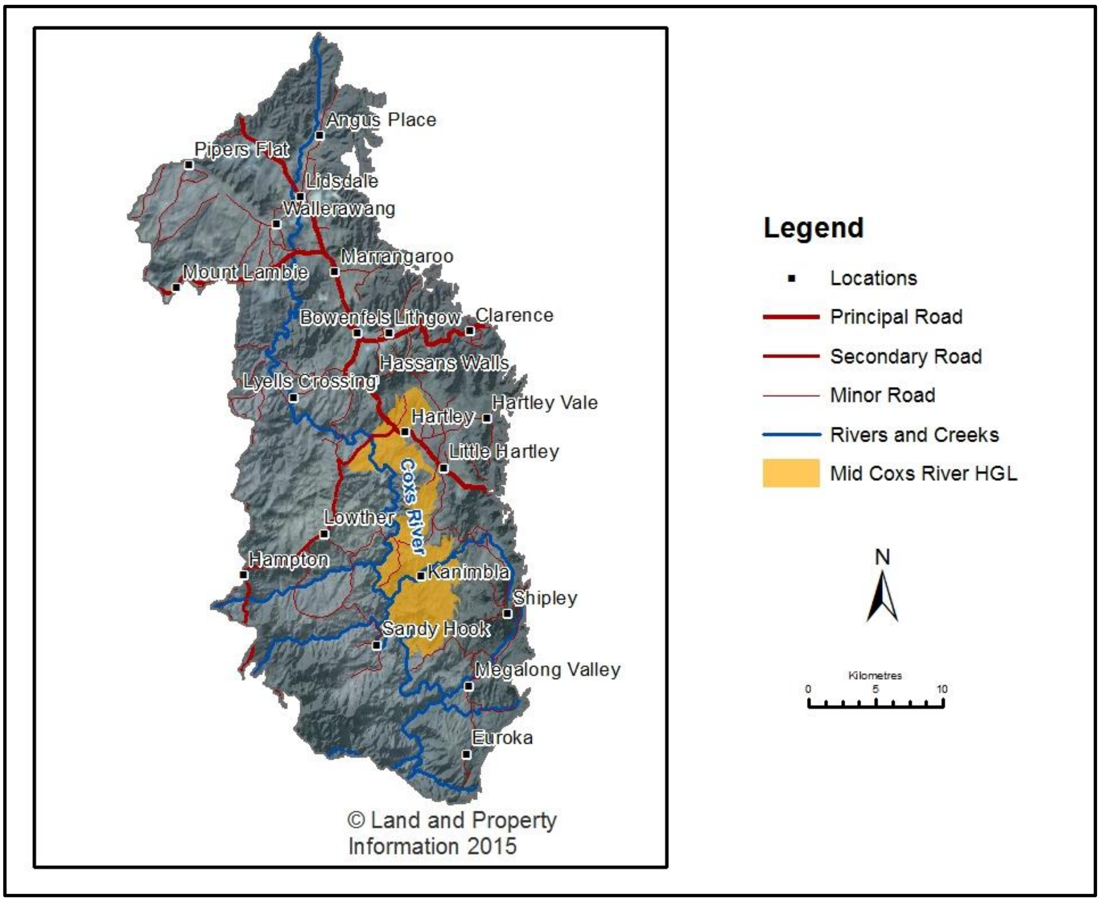


Figure 1: Mid Coxs River HGL location map.

The Mid Coxs River HGL is characterised by granitic bedrock similar to the landscapes in the Bathurst area. The landscape features rolling hills and low hills, with moderately inclined slopes. Typical lithologies for this HGL are moderately weathered granite that locally forms outcrop and subcrop on crests and upper slopes. Moderately inclined upper colluvial slopes consist of coarse sands, gravels and minor clays. Valley floors are generally incised with minor alluvial and colluvial areas of gravels with a sandy matrix. This landscape features rolling hills, low hills and rises.

Local surface water catchments are intermediate (100 ha to 500 ha). Recharge to the groundwater system (both deep and shallow) is catchment wide, but occurs mainly through the upper slopes, permeable soils and saprolite. Streams are generally ephemeral and receive discharge from groundwater as base flow. There is significant runoff in this HGL.

There is limited salt in the landscape due to moderate slopes, well drained granitic soil and short flow paths to the river. Springs are common in the lower units on this steep, exposed granitic landscape. Interception of water must be given careful consideration in this landscape because the fresh surface runoff dilutes flows to the Coxs River.

Grazing of sheep, horses and beef cattle on native and modified pasture on freehold land is the most widespread land use.

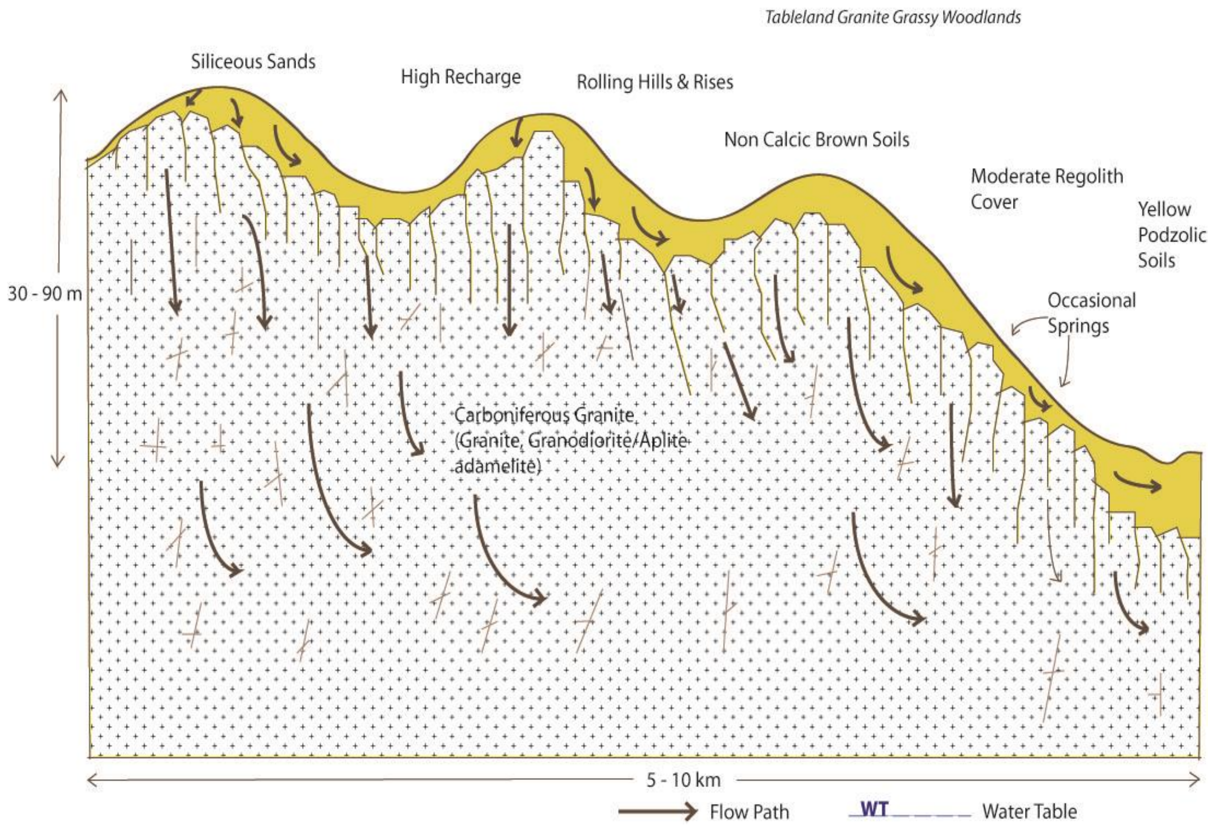


Figure 2: Conceptual cross-section for Mid Coxs River HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Mid Coxs River HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	No salt observed in this landscape.
Salt Load (Export)	Very little salt export from this landscape.
EC (Water Quality)	High quality relatively fresh water (<0.1 dS/m)

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Mid Coxs River HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Mid Coxs River HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Mid Coxs River**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Mid Coxs River HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Mid Coxs River HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Mid Coxs River**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Mount York lookout to the north-west showing the rolling hills and low hills of the Mid Coxs River HGL (Photo: DECCW/Neville Pavan).

Photo 2: View from McKanes Falls Road to the south-east showing the rolling hills and low hills of the Mid Coxs River HGL (Photo: DECCW/Neville Pavan).

Photo 3: View from McKanes Falls Road to the south-east showing rolling hills of the Mid Coxs River HGL, with crestal granite outcrop (tors <1.5 m) (Photo: DECCW/Neville Pavan).

Photo 4: View from Jenolan Caves Road to the south-east showing rolling hills of the Mid Coxs River HGL (Photo: DECCW/Neville Pavan).

Photo 5: View from Mount York lookout to the north-west showing the rolling hills and low hills of the Mid Coxs River HGL (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Mid Coxs River HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises intrusive granitic rocks from the Carboniferous period. The key lithology is: • Tarana Granite (eastern expression) – granite, granodiorite, adamellite, and aplite. This unit was formerly known as the Kanimbla Granite within the Bathurst Suite. Unconsolidated colluvial and alluvial sediments derived from the surrounding rocks have been deposited on lower slopes and along streams that pass through.
Annual Rainfall	850 mm.
Regolith and Landforms	This HGL is variably weathered but is characterised by slightly to moderately weathered granite forming low hills (30-90 m). This unit is present at altitudes between 486 m and 1200 m; with gently inclined to inclined slopes 0–30%; and limited rock outcrop. Regolith materials are dominantly quartzose coarse sandy kaolinite-bearing clays and clayey sand. Quartzose, lithic clayey sands and sandy clays are present on colluvial slopes and unconsolidated sands and gravels form the alluvium.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes from highest to lowest elevations are Marrangaroo (mry) Ben Bullen (bbz), Round Mount (mrz) and Ganbenang (gbz). Small Hassans Walls (hwz) remnants occur on the tops of some peaks and have been included in this HGL. Soil types on crests and ridges include Tenosols (Earthy Sands and Lithosols), On midslopes soils include Yellow Kurosols (Yellow Podzolic Soils). In drainage lines soils include Tenosols (Siliceous Sands, Earthy Sands) and Yellow Kurosols (Yellow Podzolic Soils). In swampy depressions Dermosols (Prairie Soils), Kurosols (Yellow Podzolic Soils) and Kandosols (Grey Earths). Minor sheet and moderate gully erosion is widespread. Severe gully erosion along drainage depressions on steeper slopes is

	locally common. Gully depth is often >1.5 m with the erosion reaching the deep weathering zone (saprolite) of granite bedrock. Severe sheet erosion is common on slopes where tree and ground cover is disturbed.
Rural Land Capability *(Emery 1986)*	Typically Class VI on upper slopes, Classes IV and V on mid and lower slopes, with Class VII on steep slopes.
Land Use	Mostly freehold land and leasehold land used for grazing of sheep, beef cattle and horses on both modified and native pastures.
Key Land Degradation Issues	**Limitations:** • Steep slopes – sheet erosion is occasionally found and, where severe, topsoil materials may be completely eroded. • Gully erosion – 1 m to 4 m deep is evident throughout the landscape particularly along most drainage lines. Stream bank erosion is common on drainage lines. Moderate gully erosion is evident along some drainage lines.
Native Vegetation *(Keith 2004; Tozer et al. 2010)*	No single vegetation community definitively represents the boundary of Mid Coxs River HGL, however the main vegetation signature is *Tableland Granite Grassy Woodland* (Tozer *et al.* 2010) which is a Southern Tableland Grassy Woodland community (Keith 2004). Other local communities have extremely limited occurrences. The Mid Coxs River HGL is extensively cleared and the remaining native vegetation is relatively consistent across the landscape. While the most common community is *Tableland Granite Grassy Woodland* (shared with neighbouring Hampton HGL particularly), other Grassy Woodland and Dry Sclerophyll Forest communities also occur in lesser frequencies. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Mid Coxs River HGL.

Aquifer Type	Unconfined in fractured rock and saprolite. Lateral flow through colluvium on lower slopes.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate. Range: 5–15%.
Hydraulic Gradient	Steep. Range: >30%.

Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: 10–20 m.
Typical Catchment Size	Medium (100–1000 ha).
Scale (Flow Length)	Local. Flow length: <8 km (short to intermediate).
Recharge Estimate	Moderate to high.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Mid Coxs River HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Mid Coxs River HGL

Appropriate overall strategies pertinent to this landscape:

- Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Mid Coxs River HGL

Focus is grazing management on the rolling landscapes, with riparian management on the valley alluvial areas.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchments' salinity contribution
- There are significant areas of native pastures left in this landscape as a seed source and basis for a sound native pasture.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Runoff from slopes to dilution flows
- Pressure of rural residential subdivision development.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

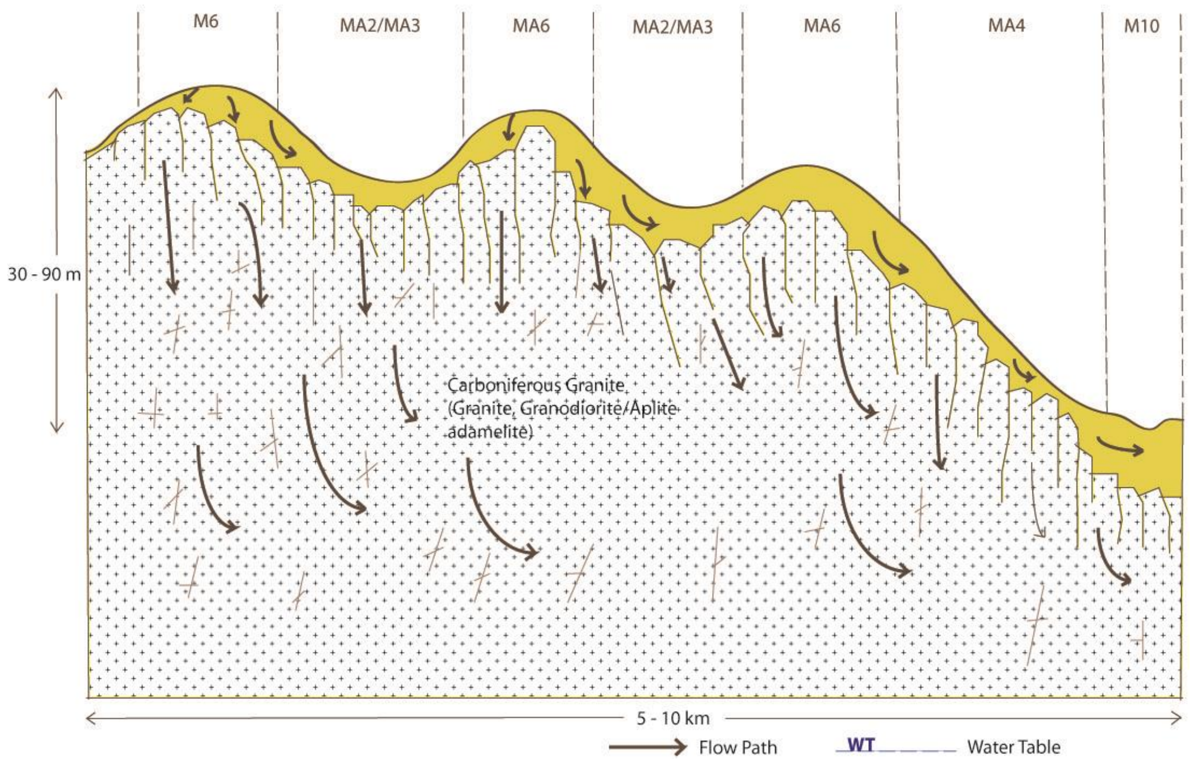


Figure 3: Management cross-section for Mid Coxs River HGL showing defined management areas.

Table 6: Specific management actions for management areas within Mid Coxs River HGL.

Management Area (MA)	Action
MA6 (Rolling rises)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service**

Management Area (MA)	Action
	Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA2 and **MA3** (Upper slopes – erosional and colluvial) – erosional and colluvium areas	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Irrigation systems** On farm irrigation BMP (IS1).
MA10 (Alluvial channel)	**Irrigation systems** On farm irrigation BMP (IS1). **Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Mid Coxs River HGL.

AT RISK MANAGEMENT AREAS	ACTION
MA2, MA3, MA4, MA6	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).
MA2, MA3, MA4, MA6	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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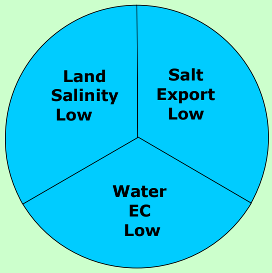
6. Mount Walker Hydrogeological Landscape

LOCALITIES	**Mount Walker**
GEOLOGY SHEET	**Sydney 1:250 000** **Bathurst 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Mount Walker Hydrogeological Landscape (HGL) is located west of Lithgow and is bounded by the Hampton HGL and Mid Coxs River HGL. The area receives >850 mm of rain per annum.

Devonian sediments predominate this HGL, and hence is vastly different to other HGLs in the area.

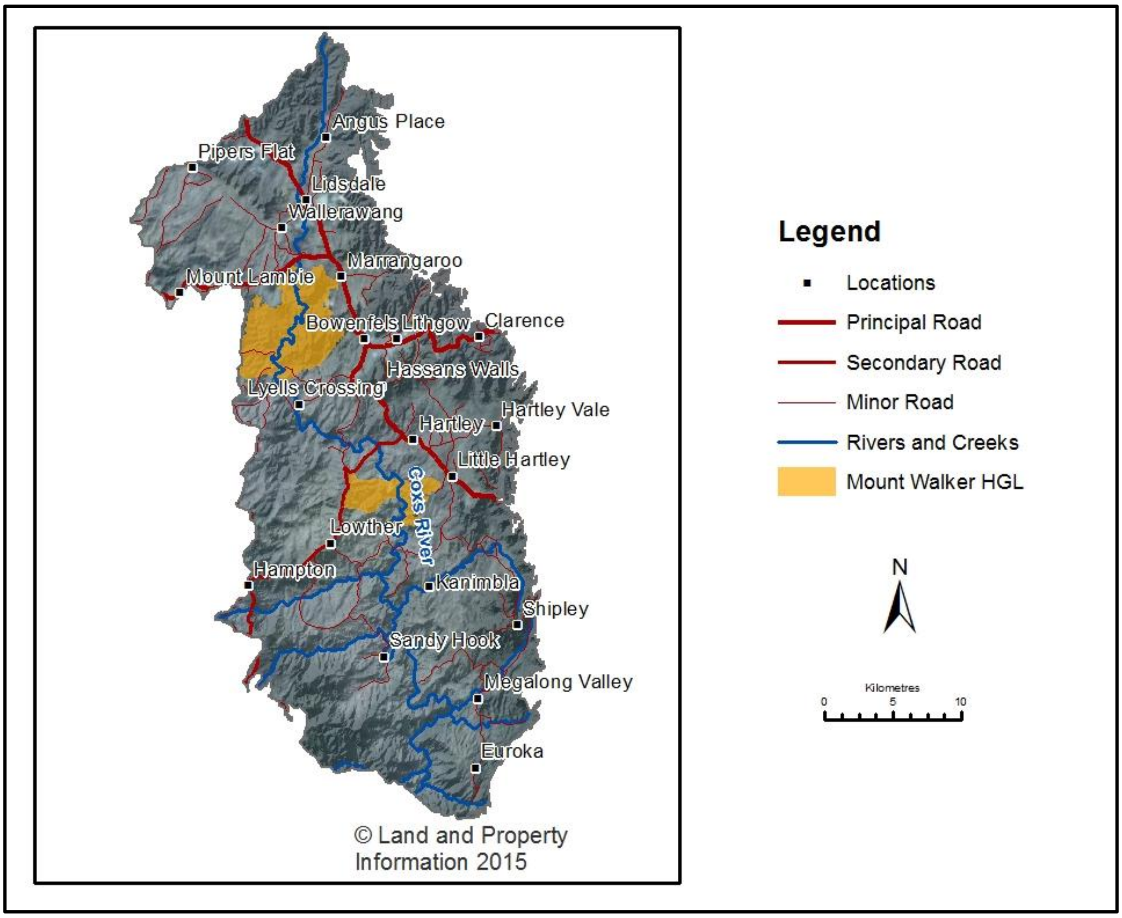


Figure 1: Mount Walker HGL location map.

The Mount Walker HGL is characterised by tilted and folded Devonian igneous and metasedimentary rocks and mixed sediments. The landscape features hills (90–200 m) forming ridges with steep slopes (25–70%). Outcrop is common (20–50%), and there is minimal soil development. Localised steep hills on rhyolite are being quarried. Typical lithologies for this HGL are folded Devonian igneous and metasedimentary rocks (quartzite, schist, phyllite, quartz-orthoclase porphyry) and mixed sediments (limestone, shale, sandstone) of the Lambie Group. They form landscapes characterised by narrow crests and steep slopes with steep and narrow deeply incised valleys. Rock outcrop and surface boulders are common.

Local surface water catchments are small (<100 ha). Recharge to the groundwater system (both deep and shallow) is catchment wide. There is significant runoff in this HGL.

There is limited salt in the landscape because there is a low capacity for salt storage and high runoff, and soils are well drained. Interception of water must be given careful consideration in this landscape because the fresh surface runoff dilutes flows to the Coxs River.

Freehold and vacant Crown land form the dominant land tenure. Small areas are contained within Lidsdale State Forest. There is light grazing on some gentler slopes. The material is highly suitable for quarrying.

Landscape limitations and hazards include steep slopes with localised sheet erosion and shallow soils throughout the landscape. Track erosion and batter collapse is seen along some of the steeper tracks and fire trails.

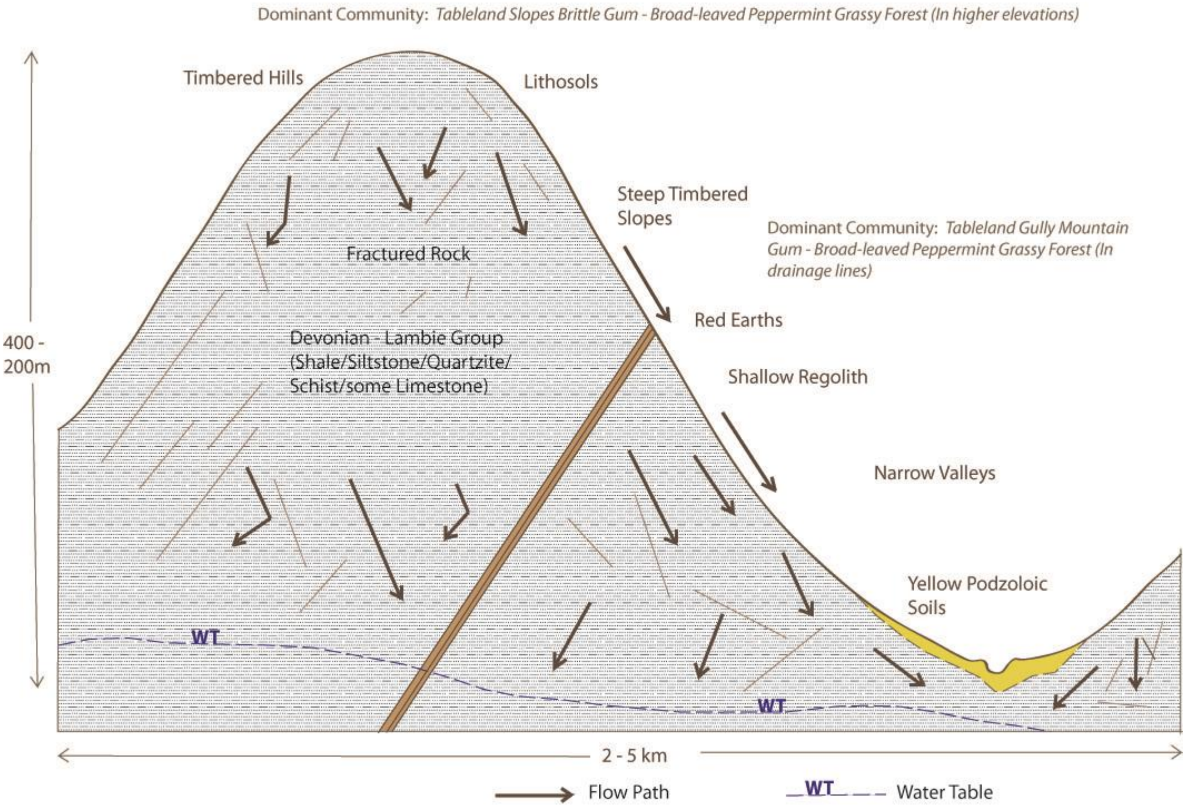


Figure 2: Conceptual cross-section for Mount Walker HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Mount Walker HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	No salt observed.
Salt Load (Export)	Limited impact.
EC (Water Quality)	High quality relatively fresh water (<0.1 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Mount Walker HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Mount Walker HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Mount Walker**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Mount Walker HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially low impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Mount Walker HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Mount Walker**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Sir Thomas Mitchell Drive to the north showing the mountains and hills of the Mount Walker HGL, including Mount Walker in the background, and low hills of the Hassans Walls HGL in the foreground (Photo: DECCW/Neville Pavan).

Photo 2: View from Sir Thomas Mitchell Drive to the north showing the steep Mount Walker Range (Mount Walker HGL) in the background and low hills and hills of the Hassans Walls HGL in the foreground (Photo: DECCW/Neville Pavan).

Photo 3: View from Jenolan Caves Road to the south-east (towards Mount Victoria) showing resistant hills formed on rhyolite of the Mount Walker HGL in the mid-ground, and low hills of the Mid Coxs River HGL in the foreground (Photo: DECCW/Neville Pavan).

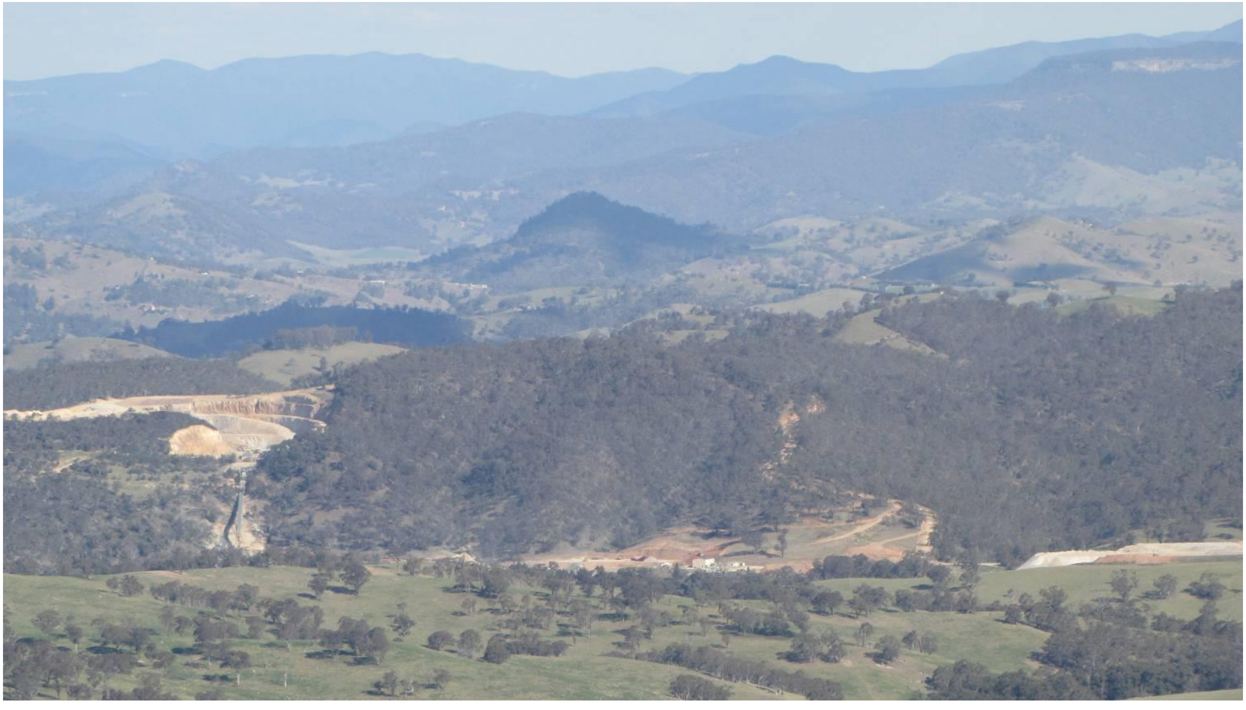


Photo 4: View from Mount York to the north-west (towards Hampton and Jenolan Caves Road) showing quarrying in rhyolite of the Mount Walker HGL in the mid-ground, and low hills and hills of the Hampton HGL in the background (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Mount Walker HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises consolidated sedimentary rocks from the Devonian period. The key lithology is: • Lambie Group – Terrigenous to shallow marine, quartz sandstone, quartzite, siltstone, mudstone, conglomerate. Unconsolidated colluvial and alluvial sediments derived from the surrounding rocks have been deposited on lower slopes and along streams that pass through.
Annual Rainfall	850 mm.
Regolith and Landforms	This HGL is moderately to slightly weathered and characterised by hills (90–200 m) forming steep ridges developed on sub vertically bedded Devonian sediments. Rock is exposed over large areas of this landscape, and there is minimal soil development. Angular surface gravels, cobbles and boulders are common. This HGL is at altitudes between 584 m–1201 m; with inclined to steep slopes (25–70%), and rock outcrop typically 20–50%. Regolith materials are dominantly angular, tabular quartzose and lithic pebble- and cobble-bearing sandy gravels and gravely sands on steep colluvial slopes. In the upper part of the landscape the regolith cover is relatively thin, and exposed rock forms the ridge crests. In the lower part of the landscape the regolith materials are angular quartzose and lithic gravel and pebble-bearing clayey sands and sandy clays.
Soil Landscapes *(DECC 2008; OEH 2017)*	This HGL is dominated by the Mount Walker (mwz) Soil Landscape. It consists of steep hills and mountains with mainly Yellow Kurosols and Kandosols (Yellow Podzolic Soils, Yellow and Red Earths) on crests to midslopes and Dermosols (Structured Earths) lower in the landscape. There is moderate sheet erosion and evidence of mass movement throughout the landscape. Track erosion and batter collapse is seen along some of the steeper tracks and fire trails.
Rural Land Capability *(Emery 1986)*	Typically Classes VII and VIII across the entire landscape.
Land Use	Freehold and vacant Crown land form the dominant land tenure. Small areas are contained within Lidsdale State Forest. There is light grazing on some gentler slopes. The volcanic rock (rhyolite) is highly suitable for quarrying.
Key Land Degradation Issues	**Limitations:** • Very steep slopes – sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded • Shallow soils.
Native Vegetation *(Keith 2004; Tindall et al. 2004; DEC 2006; Tozer et al. 2010)*	The dominant vegetation community which forms a clear signature for the Mount Walker HGL is *Tableland Slopes Brittle Gum – Broad-leaved Peppermint Grassy Forest* (DEC 2006) which is equivalent to *Western Tablelands Dry Forest* (Tindall *et al.* 2004, Tozer *et al.* 2010). Their distribution matches precisely to the boundary of the HGL, mainly in accordance with remnant

	forest which remains uncleared. *Tableland Slopes Brittle Gum – Broad-Leaved Peppermint Grassy Forest* is otherwise only found in the adjacent Angus Place HGL. The notable tree species within these equivalent communities are *Eucalyptus mannifera, E. rossii* and *E. dives.* The Mount Walker HGL is generally heavily vegetated with remnant forest such as in the northern portion of the HGL which remains under Lidsdale State Forest. Overall, the dominant vegetation communities within the HGL are Southern Tablelands Dry Sclerophyll Forests (Keith 2004), with particular significance of the signature local communities of *Tableland Slopes Brittle Gum – Broad-leaved Peppermint Grassy Forest* (DEC 2006) in the higher elevations of the HGL, and *Tableland Gully Mountain Gum – Broad-leaved Peppermint Grassy Forest* (DEC 2006) in the drainage gullies. ***See Appendix C for full vegetation descriptions for each Management Area***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Mount Walker HGL.

Aquifer Type	Unconfined in fractured rock and saprolite. Lateral flow through colluvium on lower slopes.
Hydraulic Conductivity	Moderate. Range: 10^{-2}–10 m/day.
Aquifer Transmissivity	Low to moderate. Range: <2–50 m^2/day.
Specific Yield	Low to moderate. Range: <5 –15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: >20 m.
Typical Catchment Size	Small (<100 ha).
Scale (Flow Length)	Local. Flow length: <5 km (short).
Recharge Estimate	Low.
Residence Time	Short (months).
Responsiveness to Change	Fast (months).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles must also be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Mount Walker HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source.

Landscape Management Strategies – Mount Walker HGL

Appropriate overall strategies pertinent to this landscape:

- Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.

Key Management Focus – Mount Walker HGL

Focus is management of the native vegetation, grazing management of minor cleared land and management of the potential for soil degradation (erosion and shallow soils).

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchments' salinity contribution
- There are significant areas of native vegetation in this landscape to act as a seed source and for biodiversity conservation.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Slopes are steep and catchment contributes to dilution flows
- Construction of access tracks.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

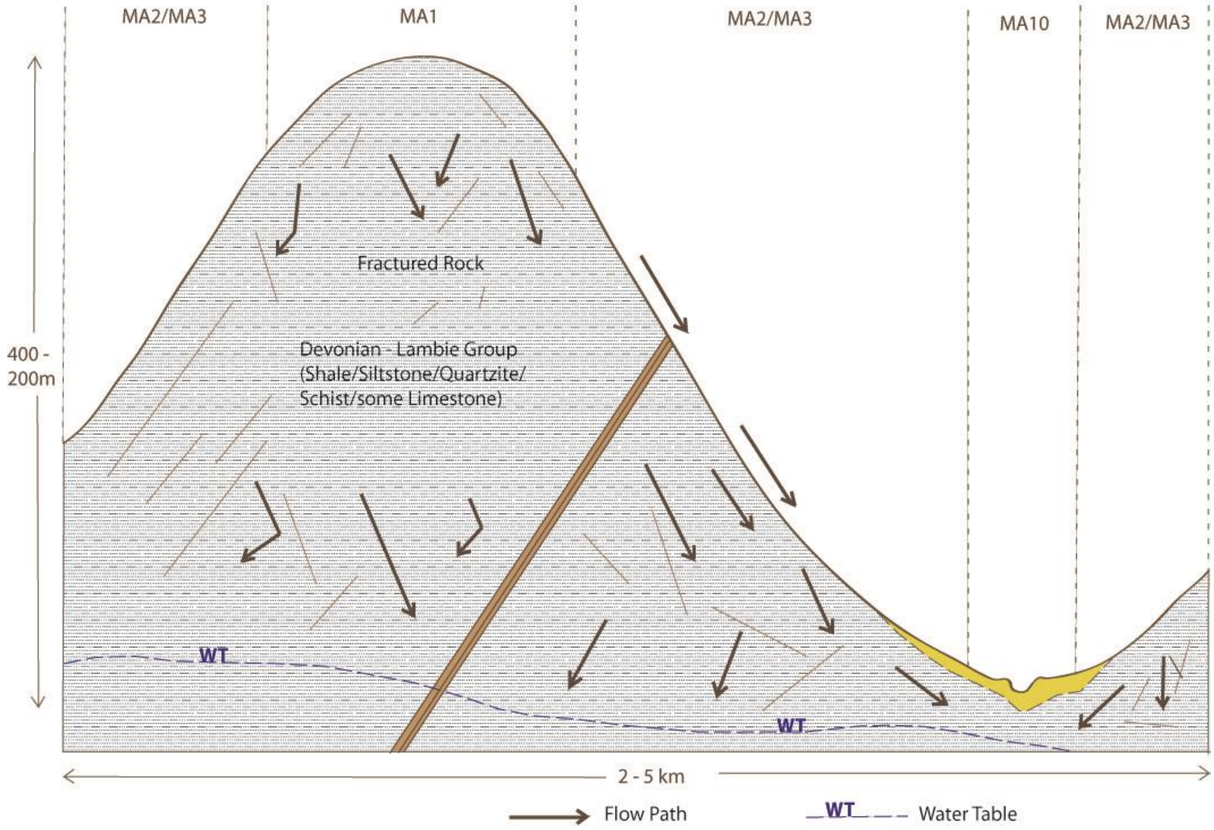


Figure 3: Management cross-section for Mount Walker HGL showing defined management areas.

Table 6: Specific management actions for management areas within Mount Walker HGL.

Management Area (MA)	Action
MA1 (Ridges) - steep	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA3 and **MA2** (Upper slopes – erosional and colluvial) – minor erosional and colluvium areas	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Mount Walker HGL.

At Risk Management Areas	Action
MA1, MA2, MA3	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

REFERENCES

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Tindall, D., Pennay, C., Tozer, M.G., Turner, K. and Keith, D.A. 2004, *Native Vegetation Map Report Series. No. 4. Araluen, Batemans Bay, Braidwood, Burragorang, Goulburn, Jervis Bay, Katoomba, Kiama, Moss Vale, Penrith, Port Hacking, Sydney, Taralga, Ulladulla, Wollongong*. NSW Department of Environment and Conservation and NSW Department of Infrastructure, Planning and Natural Resources, Sydney.

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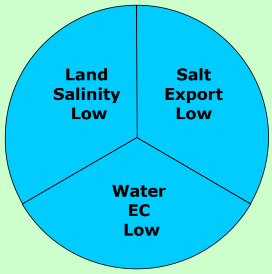
Wooldridge, A., Nicholson, A., Muller R., Jenkins, B.R., Wilford, J. and Winkler, M. 2015, *Guidelines for managing salinity in rural areas*, NSW Office of Environment and Heritage, Sydney, NSW [Accessed: 27 April 2017]. http://data.environment.nsw.gov.au/dataset/guidelines-for-managing-salinity-in-rural-areasf7236.

7. Hassans Walls Hydrogeological Landscape

LOCALITIES	**Hassans Walls, Bowenfels, Mckanes Falls**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Hassans Walls Hydrogeological Landscape (HGL) is located within the Hartley and Lithgow Valleys. The area receives >900 mm of rain per annum.

The landscape has sedimentary upper slope and lower slope developed over granite substrate in the midslopes and valley floors. The lower area of the Hassans Walls HGL is broadly similar to the Mid Coxs River HGL, as both are formed in granite terrains. The overall structure of the Hassans Walls HGL is similar to that of Megalong Valley but the latter has a longer escarpment section forming the cliff tops.

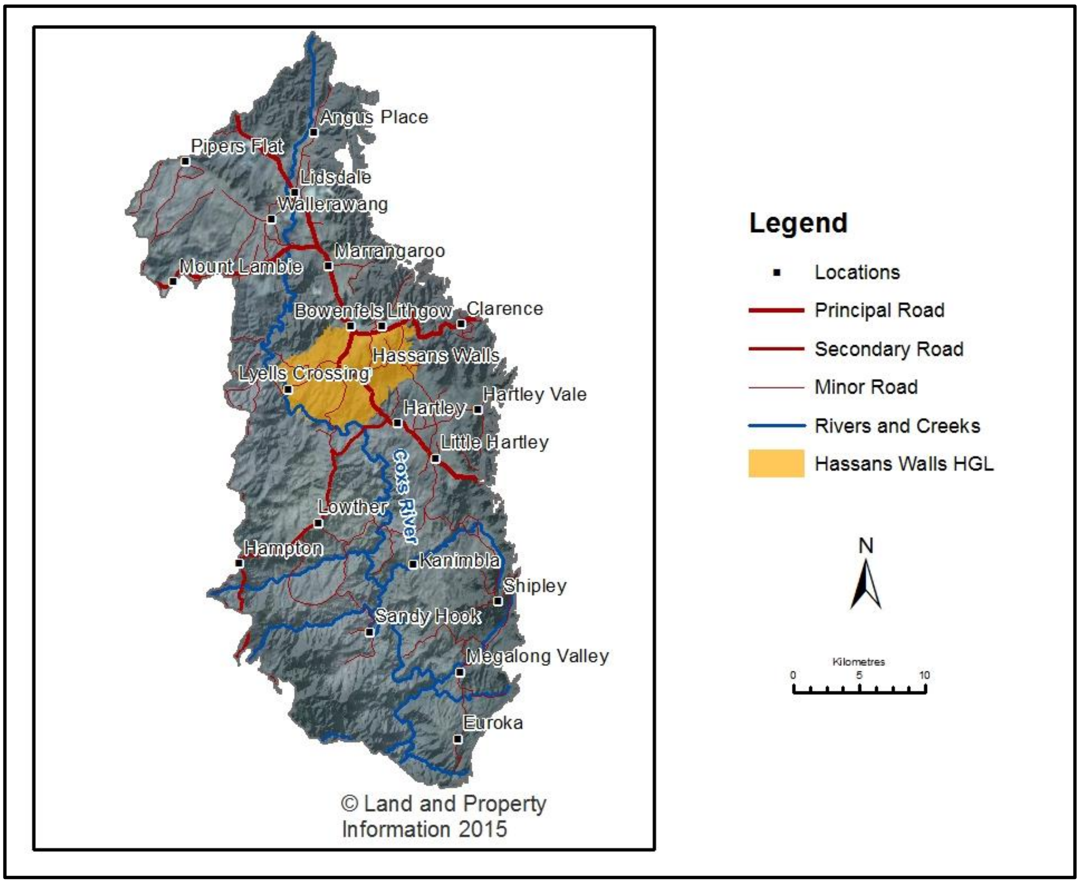


Figure 1: Hassans Walls HGL location map.

Hassans Walls HGL is characterised by flat lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale within the Hartley and Lithgow Valleys. The landscape features a short steep sandstone escarpment and a talus slope, on the sedimentary rocks and low hills and rises developed over granite substrate in the midslope and valley areas.

Typical lithologies for the upper unit of this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and major coal seams of the Illawarra Group, and siltstone, sandstone and conglomerate of the Shoalhaven Group. This landscape features resistant Narrabeen Sandstones forming a short cliff section high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, rubbly, tabular lithic pebble- to boulder-bearing sandy gravel talus slope. Moderately weathered granite with localised outcrop and subcrop forms the lower slopes and valley floor.

Water infiltrates through the plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Local surface water catchments are intermediate (<500 ha). Recharge to the groundwater system (both deep and shallow) is catchment wide. Streams are generally ephemeral and receive discharge from groundwater as base flow.

There is limited salt in the landscape because escarpment landforms are relatively free draining and do not preserve salt-bearing strata. Well drained granitic soil is found on colluvial slopes, and there are relatively short flow paths to the river.

Land use is rural and rural residential at Bowenfels and surrounds. Elsewhere woodland vegetation remains on the cliff and talus slopes. Where land is largely freehold land use is limited to grazing on native and modified pasture on cleared colluvial slopes. The area has been a main thoroughfare for transport, power, gas and communication utilities.

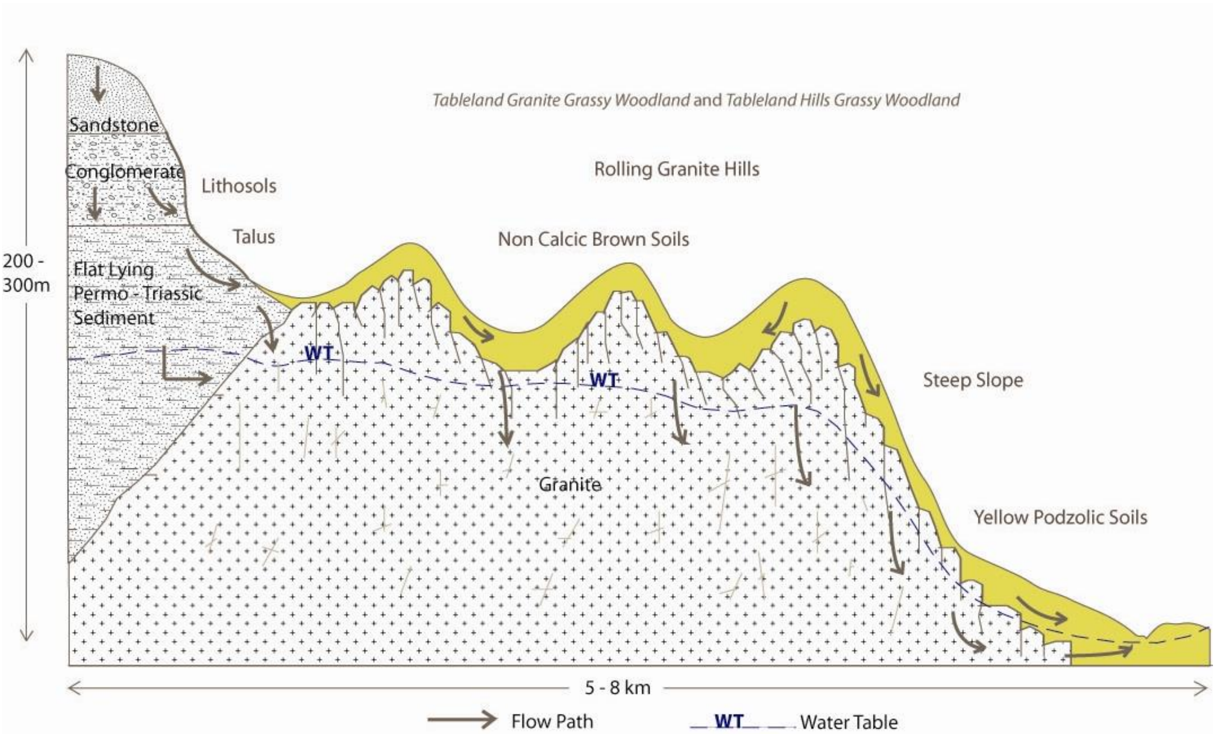


Figure 2: Conceptual cross-section for Hassans Walls HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Hassans Walls HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	No salt observed in this landscape.
Salt Load (Export)	Very little salt export from this landscape.
EC (Water Quality)	High quality relatively fresh water (<0.1 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Hassans Walls HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Hassans Walls HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Hassans Walls**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Hassans Walls HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Hassans Walls HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Hassans Walls**		

LANDSCAPE ATTRIBUTES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

Photo 1: View from Hassans Walls to the south-east showing the remnant sandstone cliff and long talus slope of the Hassans Walls HGL. This contrasts with the short vertical sandstone cliff section and concave talus slopes of the Hartley HGL in the background (Photo: DECCW/Neville Pavan).

Photo 2: View from the Hassans Walls lookout showing the crestal sandstone cliff of the Hassans Wall HGL (Photo: DECCW/Neville Pavan).

Photo 3: View from Hassans Walls lookout to the south-west showing rolling granitic low hills and hills forming the lower landscape of the Hassans Walls HGL (Photo: DECCW/Neville Pavan).

Photo 4: View from the Magpie Hollow/Tarana Road to the south showing rolling granitic low hills and hills that drop off steeply into the Coxs River (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Hassans Walls HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises intrusive granitic rocks from the Carboniferous period, and consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale (Blue Mountains Plateau and Lithgow Valley) • Illawarra Group – carbonaceous shale, grey shale, thick coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate • Tarana Granite (eastern expression) – granite, granodiorite, adamellite, and aplite. This unit was formerly known as the Kanimbla Granite within the Bathurst Suite. Unconsolidated colluvial sediments derived from the surrounding rocks have been deposited along the slopes and in depressions within this HGL.
Annual Rainfall	800–900 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep to precipitous sandstone mountain escarpments (>220 m), in the upper part of the landscape. Lower in the landscape slightly to moderately weathered granite forms low hills (30–90 m). This unit is present at altitudes between 99 m–1160 m; with inclined to steep slopes (40-100%), and rock outcrop typically 20–50%. Regolith materials in the upper part of the landscape are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands. Lower in the landscape regolith materials are dominantly quartzose coarse sandy kaolinite-bearing clays and clayey sand. Quartzose, lithic clayey sands and sandy clays are found on colluvial slopes and unconsolidated sands and gravels form the alluvium.
Soil Landscapes *(DECC 2008; OEH 2017)*	This HGL is represented by Hassans Walls (hw) and Cullen Bullen (cb) Soil Landscapes. The Hassans Walls upper soil units are: generally Siliceous Lithosols, Earthy Sands and Yellow Earths on the sandstone plateau and cliff sections with Yellow Podzolic Soils on shale lenses. Shallow Lithosols and Siliceous Sands are present on the cliff face and Yellow Podzolic Soils occur on the lower cliff face and talus slopes. Shallow siliceous Lithosols and Sands form on the crests with Yellow Earthy Sands on sideslopes, and moderately deep Earthy Sands and Yellow Earths further downslope. Lower soil units are mainly Lithosols and Siliceous Sands (Rudosols and Tenosols), Non-Calcic Brown Soil (Brown Chromosols), and Red and Brown Podzolic Soils (Red and Brown Kurosols) associated with mid slopes. Earthy Sands and Lithosols (Tenosols), Yellow Podzolic Soils (Yellow Kurosols) and Prairie Soils (Dermosols) occur on lower slopes and in depressions.

Rural Land Capability *(Emery 1986)*	Typically Class VIII for the cliff sections, Classes VII and VI for the timbered foothills, Class IV on the colluvial slopes, and Class V for localised areas.
Land Use	Land use is rural and rural residential at Bowenfels and surrounds. Elsewhere woodland vegetation remains on the cliff and talus slopes. Where land is largely freehold land use is limited to grazing on native and modified pasture on cleared colluvial slopes. The area has been a main thoroughfare for transport, power, gas and communication utilities.
Key Land Degradation Issues	**Limitations:** • Steep slopes – Sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded • Rockfall on cliffs • Sheet and rill erosion (talus areas) • Gully erosion – 1 m–4 m deep is evident throughout the landscape particularly along most drainage lines. Stream bank erosion is common on drainage lines. Moderate gully erosion is evident along some drainage lines.
Native Vegetation *(Keith 2004; Tozer et al. 2010)*	While there is no distinct vegetation signature that independently identifies Hassans Walls HGL, the succession of vegetation communities is a characteristic of this landscape. The rolling hillslopes are typically covered with Grassy Woodland (Keith 2004) communities. The vegetation on the highest ridges and plateau areas of Hassans Walls HGL is typically Heathlands and Dry Sclerophyll Forest communities (MA1) reflecting the sandstone substrate and the exposed aspect on the high sandstone cliff areas (>900 m ASL). There is a distinct vegetation change from the sandstone ridges to the upper erosional and colluvial slopes (MA2/3) where the higher altitude shrubby forests and woodlands merge into Wet Sclerophyll Forests. This broad band of Wet Sclerophyll Forests grades downslope into Dry Sclerophyll Forests, particularly on exposed features on the slopes, and then Grassy Woodlands on the mid- and lower colluvial slopes (MA4, MA5). The rises (MA6) on the valley plain and the riparian – alluvial channel areas (MA10) close to the River Lett, where not cleared, are dominated by Grassy Woodlands. Isolated stands of pine trees are present on the talus slopes. ***See Appendix C for full vegetation descriptions for each Management Area.***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Hassans Walls HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate to high. Range: 5–>15%.
Hydraulic Gradient	Steep. Range: >30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: >10 m.
Typical Catchment Size	Medium (100–500 ha).
Scale (Flow Length)	Local. Flow length: <8 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Hassans Walls HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source
- This landscape provides fresh water runoff as an important dilutions flow source
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Hassans Walls HGL

Appropriate overall strategies pertinent to this landscape:

- Maintaining and maximising runoff (10): This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- Dry out the landscape with diffuse actions over most of the landscape (6): Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also buffer groundwater accessions in wet seasonal conditions.

Key Management Focus – Hassans Walls HGL

Focus is management of the cliff face area, with remnant management and grazing management in the lower slopes and rises. Soils management adjacent to major 'roading infrastructure' is a focus to reduce off-site sedimentation and erosion.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchments' salinity contribution
- There are significant areas of native pastures left in this landscape as a seed source and basis for a sound native pasture.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Runoff from slopes to dilution flows
- Pressure of rural residential subdivision development.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

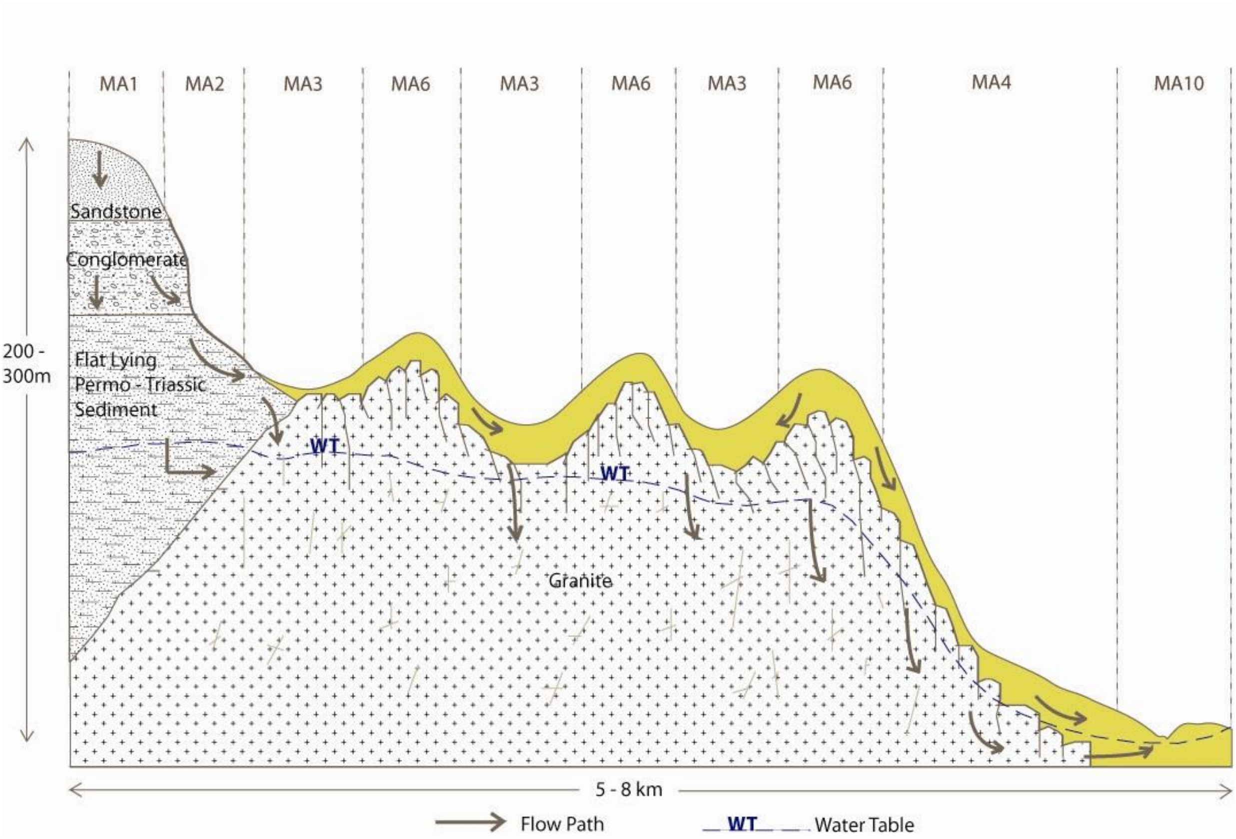


Figure 3: Management cross-section for Hassans Walls HGL showing defined management areas.

Table 6: Specific management actions for management areas within Hassans Walls HGL.

Management Area (MA)	Action
MA1 (Cliffs and escarpments)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) – steep timbered slopes **MA3** (Upper slopes – colluvial) – talus slope	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production** Maintain and improve native pastures to manage recharge (VP5).
MA6 (Rolling rises and low hills)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA3 (Upper slopes - colluvial) – colluvium between small rises	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5).

Management Area (MA)	Action
	Establishment and management of perennial pastures (VP2). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Hassans Walls HGL.

At Risk Management Areas	Action
MA3, MA4, MA6	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).
MA3, MA4, MA6	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).

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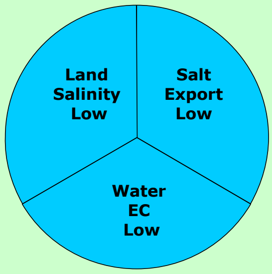
8. Megalong Valley Hydrogeological Landscape

LOCALITIES	**Megalong Valley**
GEOLOGY SHEET	**Sydney 1:250 000**
CONFIDENCE LEVEL	**Medium**



OVERVIEW

The Megalong Valley Hydrogeological Landscape (HGL) is located in the Megalong Valley near Lithgow. The area receives >900 mm of rain per annum.

The area has a cleared valley floor and wooded slopes and large cliff lines. The Megalong Valley HGL is broadly similar to the Hassans Walls HGL, however exhibits steeper landforms, and a longer escarpment section forming the clifftops.

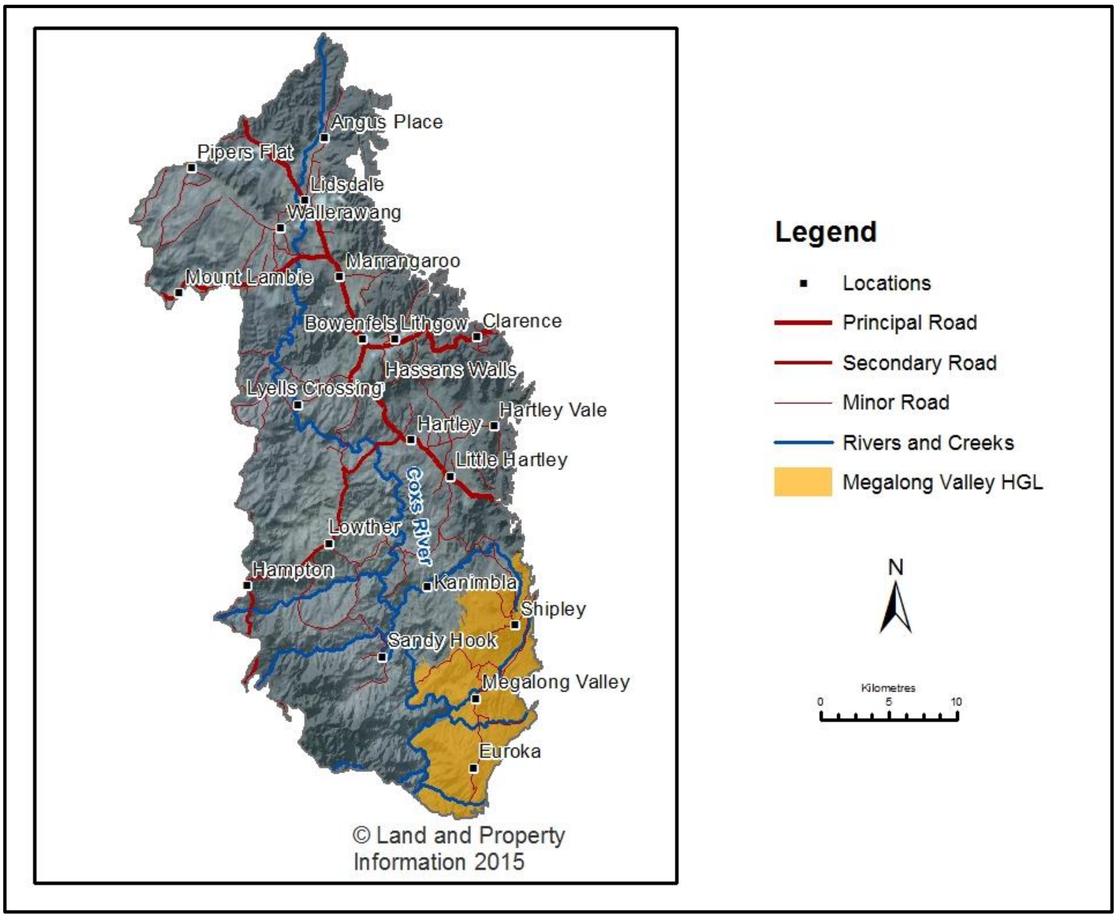


Figure 1: Megalong Valley HGL location map.

The Megalong Valley is characterised by flat lying Permo-Triassic sandstone, claystone, coal, conglomerate and shale within the Hartley and Lithgow Valleys. The landscape features a long sandstone escarpment, a steep talus slope, hills and low hills over granite in the lower parts of the sequence. The mid-slope features typically include steep rolling hills, moderately to steeply inclined colluvial slopes and drainage lines. Typical lithologies for the upper unit of this HGL are sandstone, claystone and shale of the Triassic Narrabeen Group underlain by sandstone, shale, claystone and major coal seams of the Illawarra Group, and siltstone, sandstone and conglomerate of the Shoalhaven Group. This landscape features resistant Narrabeen Sandstones forming a cliff section high in the landscape with a large part of the lower cliff section (including the lower stratigraphic units) obscured by a steep, vegetated, talus slope. Moderately weathered granite with localised outcrop and subcrop, forms the lower slopes and valley floor.

Water infiltrates through the plateau surface, high in the landscape, and moves through the fractured sedimentary rock, sometimes emerging at horizontal fractures as cliff-face springs. Water preferentially percolates downward through structures (joints, fractures, faults) in the rock material until it encounters less permeable layers in the stratigraphy, causing water to flow laterally and reach the land surface. Water also filters through the unconsolidated rocky sediments forming the talus slope. Local surface water catchments are intermediate (<1000 ha). Recharge to the groundwater system (both deep and shallow) is catchment wide. Streams are generally ephemeral and receive discharge from groundwater as base flow.

There is limited salt in the landscape because escarpment landforms are relatively free draining and do not preserve salt-bearing strata. Well drained granitic soil is present on colluvial slopes, and there are relatively short flow paths to the river.

Land use is rural (grazing and horticultural), rural residential and ecotourism throughout the Valley. Elsewhere woodland vegetation remains on the cliff and talus slopes. Where land is largely freehold land use is limited to grazing on native and modified pasture on cleared colluvial slopes. The Coxs River flows into Lake Burragorang shortly below the valley.

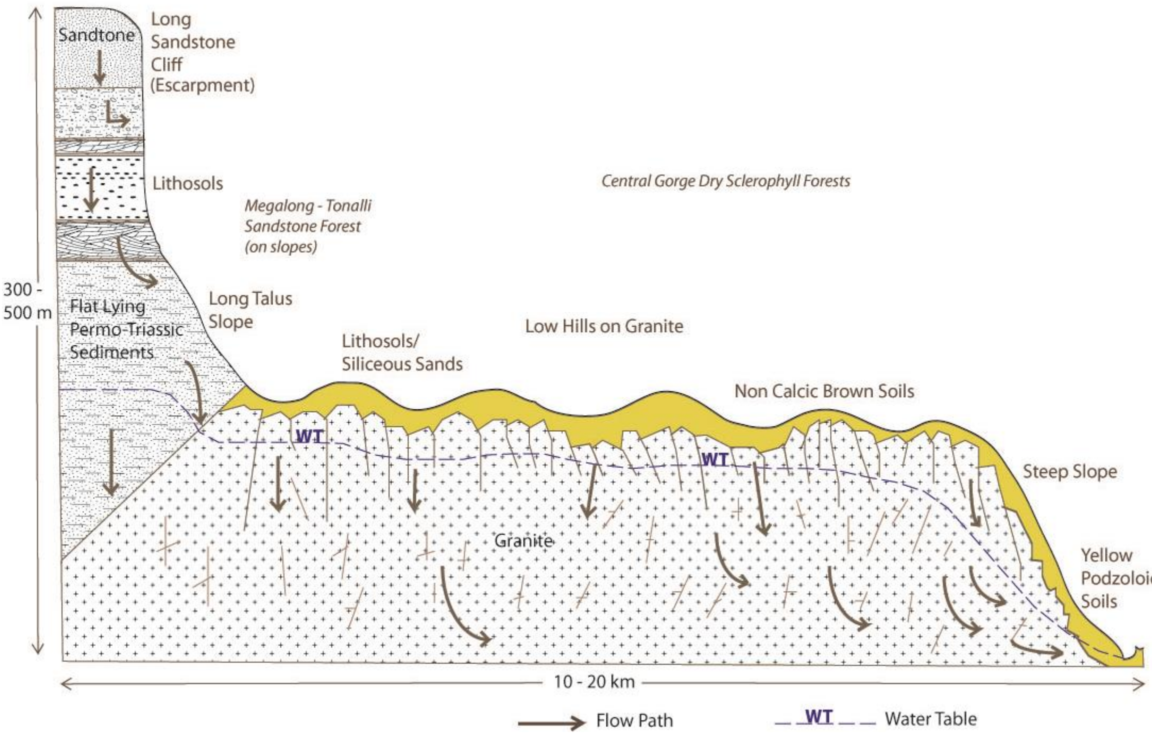


Figure 2: Conceptual cross-section for Megalong Valley HGL showing the distribution of regolith, landforms, salt sites and flow paths of water infiltrating the system.

There is evidence of land salinity in this HGL (Table 1).

Table 1: Megalong Valley HGL salinity expression.

SALINITY EXPRESSION	
Land Salinity (Occurrence)	No salt observed in this landscape.
Salt Load (Export)	Very little salt export from this landscape.
EC (Water Quality)	High quality relatively fresh water (<0.1 dS/m).

Salt store refers to the amount of salt stored in soil and geology materials. Salt availability refers to how easily this salt can be moved by water. Salt stored within Megalong Valley HGL has moderate mobility. There is a low salt store that has high availability (Table 2).

Table 2: Megalong Valley HGL salt store and availability.

SALT MOBILITY			
	Low availability	**Moderate** availability	**High** availability
High salt store			
Moderate salt store			
Low salt store			**Megalong Valley**

Overall salinity hazard is based on the likelihood of salinity occurring and how much impact it will have. The overall salinity hazard in Megalong Valley HGL is very low. This is due to the low likelihood that salinity issues will occur and that they would have potentially limited impacts (Table 3).

Table 3: Likelihood of salinity occurrence, potential impact and overall hazard of salinity for the Megalong Valley HGL.

OVERALL SALINITY HAZARD			
	Limited potential impact	**Significant** potential impact	**Severe** potential impact
High likelihood of occurrence			
Moderate likelihood of occurrence			
Low likelihood of occurrence	**Megalong Valley**		

LANDSCAPE FEATURES

The following photographs illustrate landscapes and specific features observed in this HGL. Information used to define the HGL is summarised in Table 4.

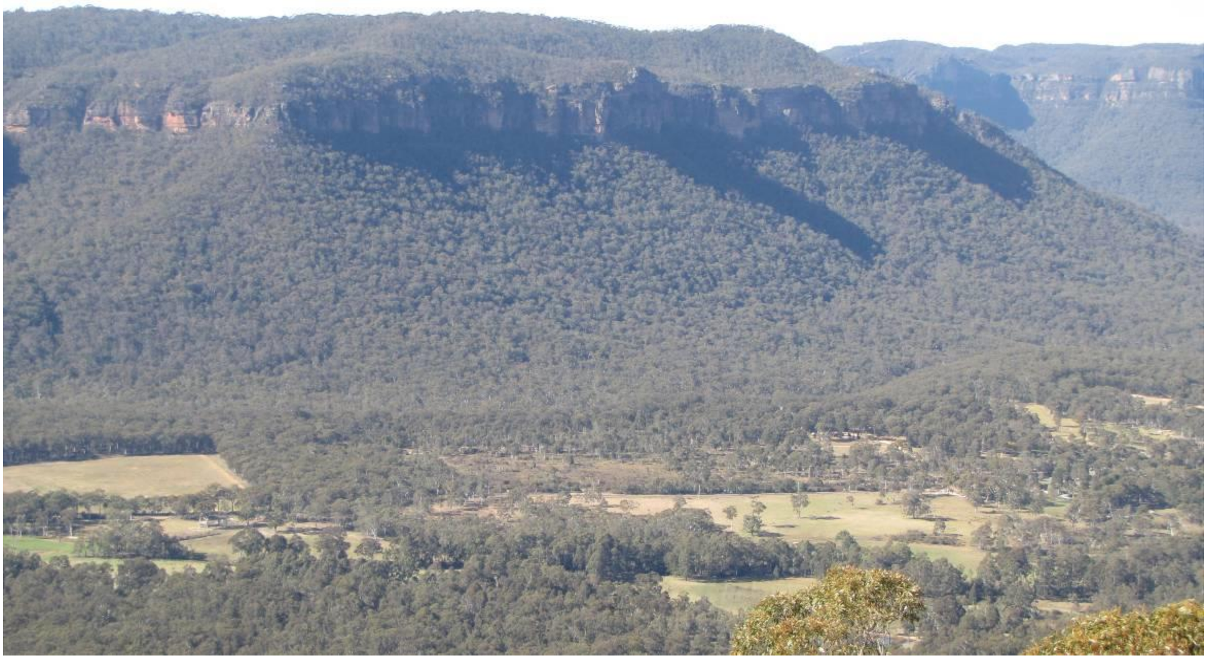


Photo 1: View from Hargreaves Lookout, Shipley Plateau, to the south-east showing the long sandstone cliff sections and talus slopes of the Megalong Valley HGL in the background, with gently to moderately inclined colluvial slopes in the foreground (Photo: DECCW/Neville Pavan).

Photo 2: View from Megalong Valley Road to the east showing the long sandstone cliff sections and talus slopes of the Megalong Valley HGL in the background, with gently to moderately inclined colluvial slopes in the foreground (Photo: DECCW/Neville Pavan).

Photo 3: View from Hargreaves Lookout, Shipley Plateau, to the south-west showing the gently to moderately inclined colluvial slopes of the lower Megalong Valley HGL in the foreground, dropping steeply into the more incised drainage systems to the west (Photo: DECCW/Neville Pavan).

Photo 4: View from Peachtree Road to the south showing low hills and hills of the Megalong Valley HGL, with moderately to steeply inclined colluvial slopes proximal to the Coxs River (Photo: DECCW/Neville Pavan).

Photo 5: View from Peachtree Road to the south showing low hills and hills of the Megalong Valley HGL, with moderately to steeply inclined colluvial slopes proximal to the Coxs River (Photo: DECCW/Neville Pavan).

Table 4: Summary of information used to define Megalong Valley HGL.

Lithology *(Rasmus et al. 1969; Geoscience Australia 2016)*	This HGL comprises intrusive granitic rocks from the Carboniferous period, and consolidated sedimentary rocks from the Permian and Triassic periods. Key lithologies include: • Narrabeen Group – quartzose sandstone, quartz-lithic sandstone, claystone, shale (Blue Mountains Plateau and Lithgow Valley) • Illawarra Group – carbonaceous shale, grey shale, thick coal seams • Shoalhaven Group – siltstone, lithic sandstone, conglomerate • Tarana Granite (eastern expression) – granite, granodiorite, adamellite, and aplite. This unit was formerly known as the Kanimbla Granite within the Bathurst Suite. Unconsolidated colluvial sediments derived from the surrounding rocks have been deposited along the slopes and in depressions within this HGL.
Annual Rainfall	800–900 mm.
Regolith and Landforms	This HGL is moderately weathered and characterised by a layered stratigraphy of bedded and fractured siliceous sandstone, claystone and shale of the Shoalhaven, Illawarra and Narrabeen Groups. These form steep (32–55%) to precipitous sandstone mountain escarpments (>220 m), in the upper part of the landscape. Lower in the landscape slightly to moderately weathered granite forms low hills (30–90 m). This unit is present at altitudes between 560 m and 1041 m; with gently inclined slopes 0% to 30% lower in the landscape; and rock outcrop is common.

	Regolith materials in the upper part of the landscape are moderately weathered and dominantly angular tabular pebble- to boulder-bearing coarse sandy gravels and gravelly sands. Lower in the landscape regolith materials are dominantly quartzose coarse sandy kaolinite-bearing clays and clayey sand. Quartzose, lithic clayey sands and sandy clays are present on colluvial slopes and unconsolidated sands and gravels form the alluvium.
Soil Landscapes *(DECC 2008; OEH 2017)*	Soil landscapes include from highest to lowest Marrangaroo (mry) and Round Mountain (rm) on granitic material and Wollangambe (wox), Medlow Bath (mbz), Hassans Walls (hwz), Cullen Bullen (cbz), and Lithgow (lix) on sediments. For the granitic areas Tenosols (Siliceous Sands, Earthy Sands) occur on crests and steeper slopes, and Yellow Kurosols (Yellow Podzolic Soils) are typically found on gentler and lower slopes. For the sediments soil types on crests and upper slopes include Rudosols (Siliceous Sands/Lithosols) and Orthic and Bleached-Orthic Tenosols (Lithosols, Siliceous Sands and Earthy Sands). On midslopes typical soil types are Yellow and Brown Kandosols (Yellow and Brown Earths) and Kurosols (Yellow, Red and Brown Podzolic Soils). Drainage lines contain Kurosols and Sodosols (Yellow Podzolic Soils, Solodised Solonetz). Streams and rivers characteristically have Tenosols (Grey-Brown Alluvial Soils) and Kurosols (Yellow Podzolic Soils and Soloths). For the granites severe gully erosion along drainage depressions on steeper slopes is common. Severe sheet erosion is common on slopes where tree and ground cover is disturbed. For the sediments soils are generally infertile. Soils are sodic and readily disperse on lower slopes and in minor drainage lines. Moderate gully erosion is evident along some drainage depressions. Minor sheet erosion is common where ground cover has been disturbed by clearing.
Rural Land Capability *(Emery 1986)*	Typically Class VIII for the cliff sections, Classes VII and VI for the timbered foothills, Class IV on the colluvial slopes, and Class V for localised areas.
Land Use	National parks and agriculture are the major land uses. Mostly freehold land and leasehold land is used for grazing of sheep, beef cattle and horses on both modified and native pastures and locally for horticulture. Land use also includes rural residential and ecotourism.
Key Land Degradation Issues	**Limitations:** • Steep slopes – Sheet erosion is occasionally present and, where severe, topsoil materials may be completely eroded. • Rockfall on cliffs. • Sheet and rill erosion (talus areas). • Gully erosion – 1 m to 5 m deep is evident throughout the landscape particularly along most drainage lines. Stream bank erosion is common on drainage lines. Moderate gully erosion is evident along some drainage lines.
Native Vegetation	**Signature:** No single vegetation community definitively represents the boundary of Megalong HGL however most

(Keith 2004; Tozer et al. 2010)	vegetation communities are Dry Sclerophyll Forests (Keith 2004). The transition of communities across the landscape from east to west is distinctive: from *Megalong- Tonalli Sandstone Forest* through *Kowmung-Wollondilly Grassy Gorge Woodland* in the east of the HGL to *Wollondilly-Cox- Shoalhaven Gorge Woodland* in the west. **Transect:** The major (distinguishing) vegetation community found on all upper talus slopes in the east of the HGL is *Megalong-Tonalli Sandstone Forest* (Tozer *et al.* 2010). On the colluvial slopes in this area are continuous stands of *Kowmung-Wollondilly Grassy Gorge Woodland* (Tozer *et al.* 2010). *Wollondilly-Co-Shoalhaven Gorge Woodland* (Tozer *et. at* 2010) is also a major vegetation community particularly in the west of the HGL, shared with adjacent Hampton HGL, on the mid-slopes that drain into the Coxs River and on colluvial slopes and rises. Minor vegetation components that occur throughout the HGL include Grassy Woodlands, Heath and other Dry Sclerophyll Forests (Keith 2004). Significantly, the rainforest community of *Grey Myrtle Dry Rainforest* (Tozer *et al.* 2010) occurs in pockets on the south-western facing slopes of Tinpot Hill and are almost exclusive to this HGL. The environmentally significant (but very minor) representation of *Blue Mountains-Shoalhaven Hanging Swamps* (Tozer *et al.* 2010) within this HGL is present on the Shipley Plateau. ***See Appendix C for full vegetation descriptions for each Management Area***

HYDROGEOLOGY

Typical values for the hydrogeological parameters of this HGL are summarised in Table 5.

Table 5: Summary of values for typical hydrogeological parameters of Megalong Valley HGL.

Aquifer Type	Unconfined in fractured rock and through sandstone pores (dual porosity). Lateral flow through unconsolidated colluvial sediments on slopes.
Hydraulic Conductivity	Moderate to high. Range: 10^{-2}–>10 m/day.
Aquifer Transmissivity	Moderate. Range: 2–100 m^2/day.
Specific Yield	Moderate to high. Range: 5–>15%.
Hydraulic Gradient	Moderate to steep. Range: 10–>30%.
Groundwater Salinity	Fresh. Range: <0.8 dS/m.
Depth to Water Table	Deep. Range: >10 m.
Typical Catchment Size	Medium (100–500 ha).

Scale (Flow Length)	Local. Flow length: <10 km (short to intermediate).
Recharge Estimate	High.
Residence Time	Short to medium (months to years).
Responsiveness to Change	Fast to medium (months to years).

MANAGEMENT OPTIONS

Overarching salinity management strategies have specific biophysical outcomes. These are achieved by implementing a series of targeted land management actions that consider the opportunities and constraints of the HGL. The actions recognise the need for diffuse and specific activities within the landscape to impact on salinity. Further explanation of land management functions, strategies and actions can be found in Wooldridge *et al.* (2015).

Salinity is driven by interactions between the water-use capacity of vegetation, soil physical properties and hydrogeological processes within the HGL.

Actions that influence the way water is used by vegetation or stored in the soil profile will impact on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events must be considered when deciding on appropriate management actions. Short and long-term climate cycles also must be considered as they have a bearing on salinity processes, particularly salt load and land salinity.

Landscape Function – Megalong Valley HGL

Functions this landscape provides within a catchment scale salinity context:

- This landscape provides fresh runoff as an important water source.
- This landscape provides fresh water runoff as an important dilutions flow source.
- This landscape provides important base flow to local streams.

Landscape Management Strategies – Megalong Valley HGL

Appropriate overall strategies pertinent to this landscape:

- **Maintaining and maximising runoff (10):** This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use in order to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Key Management Focus – Megalong Valley HGL

Focus is to manage the large cliff faces and remnant vegetation on talus and lower slopes, as well as grazing management on the valley floor along with riparian management adjacent to streams. There are large areas of remnant vegetation in this HGL.

Specific Land Management Opportunities

Specific opportunities for this HGL:

- Fresh water catchment that dilutes the impacts of other catchment's salinity contribution.
- There are significant areas of native pastures left in this landscape to act as a seed source and basis for a sound native pasture.

Specific Land Management Constraints

Constraints for land management in this HGL include:

- Runoff from slopes to dilution flows.
- Pressure of rural residential subdivision development.
- Irrigation needs to be well targeted and well managed.

Specific Targeted Actions

Management areas for this HGL are illustrated in Figure 3. The specific management actions for these areas are described in Table 6.

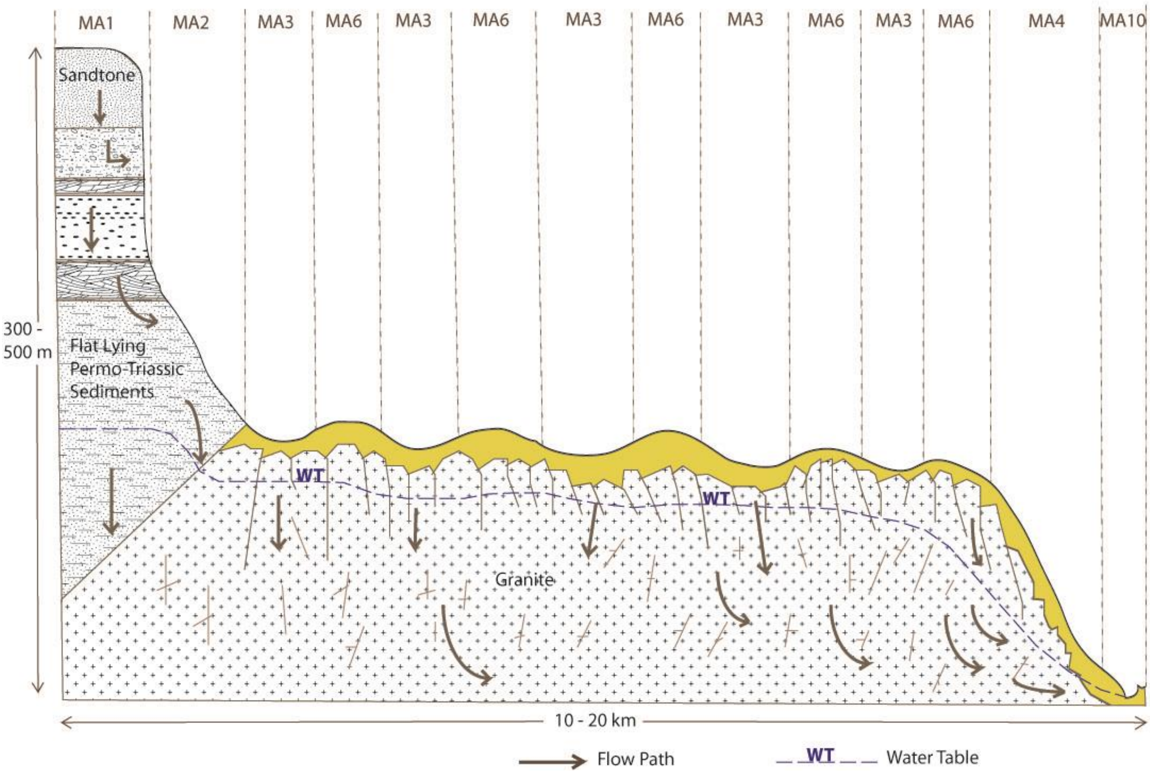


Figure 3: Management cross-section for Megalong Valley HGL showing defined management areas.

Table 6: Specific management actions for management areas within Megalong Valley HGL.

Management Area (MA)	Action
MA1 (Cliffs and escarpments)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3).
MA2 (Upper slopes – erosional) – steep timbered slopes **MA3** (Upper slopes – colluvial)	**Vegetation for ecosystem service** Maintain and improve native woody vegetation (VE3). Revegetation of non-agricultural land with native species to manage recharge (VE6). **Vegetation for production**

Management Area (MA)	Action
– talus slope	Maintain and improve native pastures to manage recharge (VP5).
MA6 (Low hills)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3).
MA3 (Upper slopes – colluvial) – colluvium between small rises	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Maintain and improve native pastures to manage recharge (VP5). Establishment and management of perennial pastures (VP2). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1).
MA4 (Mid slopes)	**Vegetation for production** Improve grazing management of existing perennial pastures to manage recharge (VP1). Establishment and management of perennial pastures (VP2). Maintain and improve native pastures to manage recharge (VP5). Perennial horticulture to manage recharge (VP9). **Vegetation for ecosystem service** Revegetation of non-agricultural land with native species to manage recharge (VE6). Maintain and improve native woody vegetation (VE3). **Farming systems** Pasture cropping with annual cereals into perennial pastures to manage recharge (FS1). **Irrigation systems** On farm irrigation management BMP (IS1).
MA10 (Alluvial channel)	**Vegetation for ecosystem service** Maintain and improve riparian native vegetation (VE4).

High Hazard Land Use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity (Table 7).

Table 7: Management actions having negative salinity impacts in the Megalong Valley HGL.

At Risk Management Areas	Action
MA3, MA4, MA6	Excessive planting of woody vegetation will compromise the fresh water contribution from this HGL (DLU6).

At Risk Management Areas	Action
MA3, MA4, MA6	Ineffective grazing systems – limits the ability of plants to use available moisture. This can increase deep drainage, recharge and salinity (DLU2).
MA6	Clearing of native vegetation – clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge (DLU4).
MA4	Use irrigation using poor practices (DL13). Poor targeting of locations suitable for irrigation (DL14).

REFERENCES

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Appendix C: Vegetation communities

Capertee Valley HGL Unit Name	Management Areas	Vegetation Communities (Local Class) in corresponding Management Area
1. Bourbin Hills	MA 2/3, 6 & 8: Erosional and Colluvial Slopes, Rises and Structures	MU19, MU20
2. Brogan View	MA 2/3 & 5: Erosional Upper Slopes and Colluvial Upper and Lower Slopes	MU9,
3. Dunns Farm	MA1: Ridges	MU43, MU10, MU27, MU29, MU38
	MA 2: Erosional Upper Slopes	MU3, MU21
	MA 3: Colluvial Upper Slopes	MU17, MU19, MU20, MU21,
	MA 4: Colluvial Midslopes	MU17, MU20
	MA 5: Colluvial Lower Slopes	MU17, MU19, MU20
	MA 10: Riparian	No local class
4. Dunville Homestead	MA 1: Ridges	MU43, MU10, MU27, MU29, MU38
	MA 2: Erosional Upper Slopes	MU3, MU21, MU38, MU13, MU19, MU20
	MA 5: Colluvial Lower Slopes	MU38, MU17, MU19, MU20
	MA 10: Riparian	MU20, MU54, MU57
5. Genowlan Mountain	MA 1: Ridges	MU10, MU43, MU44, MU47, MU8, MU27, MU29, MU4
	MA 2: Upper (Talus) Slopes	MU2, MU3, MU21, MU38, MU40
	MA 5: Lower Slopes - Colluvial	MU3, MU20, MU42
6. Glen Alice	MA 6: Rises	MU21, MU42, MU16, MU17, MU18, MU20, MU19
	MA 5: Lower Slopes - Colluvial	MU38, MU19, MU20
	MA 9: Alluvial Plains	MU13, MU19, MU20
	MA 10: Riparian - Alluvial Channel	MU54
7. Glen Davis	MA 1: Ridges	MU43, MU44, MU30
	MA 2/3: Erosional and Colluvial Upper Slopes	MU3, MU21, MU27, MU40, MU41, MU17, MU20
	MA 9: Alluvial Plains	MU19, MU20, MU54
8. Horse Gap	MA 1: Ridges	MU43, MU21, MU30, MU27, MU38
	MA 2: Upper (Talus) Slopes	MU21, MU30, MU27, MU38, MU8, MU3, MU17
	MA 2/3: Lower Talus and Upper Colluvial Slopes	MU21, MU13, MU17, MU20
	MA 4, 6, 9 & 10: Lower Colluvial Slopes, Rises, Alluvial Plains and Riparian	MU17, MU19, MU20,

Capertee Valley HGL Unit Name	Management Areas	Vegetation Communities (Local Class) in corresponding Management Area
9. Marlyn Gate	MA 1: Ridges	MU21, MU30
	MA2: Erosional Upper Slopes	MU30, MU27, MU38
	MA4: Erosional Bench	MU17
	MA5: Lower Colluvial Slopes	MU17, MU20
	MA 6: Rises	MU17, MU19, MU20
	MA 10: Riparian	MU19, MU20
10. Mount Marsden	MA 1: Ridges	MU43, MU21, MU30, MU38
	MA 2/3: Upper Erosional & Colluvial Slopes	MU3, MU8, MU21, MU27, MU29, MU30, MU38, MU41
	MA 4: Colluvial Midslopes	MU38, MU41, MU17,
	MA 5: Colluvial Lower Slopes	MU38, MU17, MU20, MU21, MU42
	MA 6: Rises	MU19, MU20
	MA 9: Alluvial Plain	MU20
	MA 10: Riparian - Alluvial Channel	MU19, MU20
11. Nile	MA 1: Ridges	MU43, MU30
	MA 2/3: Erosional and Colluvial Upper Slopes	MU2, MU3, MU21, MU27, MU38, MU40, MU41, MU17
	MA 4: Colluvial Midslopes	MU41, MU17, MU19, MU20
	MA 9: Alluvial Plains	MU17, MU19, MU20, MU54
12. Port Macquarie Station	MA6: Rises	MU42, MU21, MU38, MU39, MU13, MU16, MU18, MU19, MU20, MU54

Appendix D: Data sources

The boundaries for each Hydrogeological Landscape unit have been derived from a number of data sources. All data is based on the GDA94 coordinate system.

The details of the data sets used and the supplying agencies follow:

Agency	Data set	Description
Office of Environment and Heritage (OEH)	Soil and Land Resources of the Hawkesbury-Nepean Catchment	A DVD product comprising 21 interactive maps showing distribution of soil landscapes across the Hawkesbury-Nepean Catchment plus their specific capabilities, hazards and limitations. SPOT imagery for the catchment is included, as well as hyperlinked reports providing specific biophysical information for each soil landscape.
	NSW Soil and Land Information System (SALIS)	State-wide dataset of soil profiles, comprising (at time of writing) ~70,000 separate observations of soil physical and chemical characteristics, along with, in most cases, information about the landscape in which they occur (including landform, geology, vegetation, hydrology, land use and land degradation). Data are added by NSW Government agencies and members of the wider community using standardised Soil Data Cards.

Agency	Data set	Description
OEH *cont.*	NSW Vegetation Information System (VIS) – VIS_ID 982 (Wallerawang) – VIS_ID 1849 (Wollemi) – VIS_ID 2192 (inc. Katoomba) – VIS_ID 2230 (southeast NSW) – VIS_ID 2231 (Western Blue Mountains)	The Vegetation Information System Classification (VIS Classification) is the database for plant community types in New South Wales. It provides a consistent hierarchical vegetation classification of New South Wales plant community types, and provides public access to information on these plant community types.
	BIOCLIM 2009	35 bioclimatic layers have been generated for NSW using supplied climate surfaces at 250 m. They are based on the Geoscience Australia 9 second DEM. These layers were generated using ANUCLIM Beta Version in November 2009.
Geoscience Australia	1:1 million Geology of Eastern Australia	The NSW component of this dataset is a detailed seamless geology coverage for the state. The dataset was compiled primarily from the NSW Department of Mineral Resources statewide 1:250 000 and 1:100 000 database, as well as several broader scale regional datasets in the Broken Hill and Murray Basin areas. The work involved edge-matching over 40 individual maps and applying a consistent stratigraphic and regolith classification scheme across the state and into QLD and VIC.

Agency	Data set	Description
Geoscience Australia *cont.*	1 Second DSM and DEM elevation data – Shuttle Radar Topographic Mission (SRTM)	The national 1 second (~30 m) DEMs suite contains three publicly released national models; Digital Elevation Model (DEM), Smoothed DEM (DEM-S) and Hydrologically Enforced DEM (DEM-H). These 1 second products are a significant improvement on the SRTM digital surface model (DSM) from which they were derived.
	GEODATA TOPO 250K Series 3	Major topographic features appearing on the 1:250 000 scale including cartography, elevation, framework, habitation, hydrography, infrastructure, terrain, transport, utility and vegetation.
Geological Survey of NSW	Bathurst 1:250 000 Geological Series Sheet SI 55-08, first edition (1968)	Geological Survey of NSW published hard copy geological maps that form part of the "standard series" maps published at 1:250 000 and 1:100 000 scale. Modern maps have good detail and comprehensive depictions of geology. Note that sheets published prior to 1980 may lack the detail present in later maps.
	Bathurst 1:250 000 Geological Series Sheet SI 55-08, second edition (1998)	
	Singleton 1:250 000 Geological Series Sheet SI 56–01, first edition (1969)	
	Sydney 1:250 000 Geological Series Sheet SI 56-05, third edition (1966)	
Land and Property Information	New South Wales DTDB Landform Theme 50K Digital Terrain Models	Digital Terrain Models created from existing 10 metre and 20 metre contours sourced from the NSW Topographic Map Archive. The Data Base contains raster height data in 25 metre pixels for the Eastern and Central Divisions of the NSW. The Sydney Basin is supplemented by the integration of 2 metre contour data.

Agency	Data set	Description
Land and Property Information *cont.*	New South Wales Digital Topographic Database DTDB	Themes include a cultural layer incorporating transportation, facilities and utilities; drainage / hydrography; contours; buildings; built up areas; distinctive land surfaces and a names layer Data generally correspond to 1:25 000, 1:50 000 and 1:100 000 mapping areas represented on the Australian National Map Sheet Breakdown System.

Appendix E: Dataset attribute table information and colour schemes

Attribute Table Header

The attribute table attached to the HGL geodatabase contains the information used to describe HGLs. The following table summarises the attributes used and the ranges used for each attribute.

	HGL_no	HGL	Salt_land	Xport_Strm	EC_stream	Sodicity	Salt_store	Salt_avail	Haz_impact	Haz_likeli	Haz_ovrall	Data_Sourc	Function	Strategy
Attribute Description	HGL number	HGL name	Impact of land salinity in HGL (circular chart)	Impact of Salt export in HGL (circular chart)	Impact of water quality in HGL (circular chart)	Sodicity hazard in HGL (only recorded if high)	Salt store in HGL (salt mobility table)	Salt availability in HGL (salt mobility table)	Potential impact of salinity in HGL (hazard table)	Likelihood of salinity occurring in HGL (hazard table)	Overall salinity hazard in HGL (hazard table)	Reliability/ integrity of boundary definition data sources	Landscape functions of HGL (management options)	Management strategy objectives for HGL (management options)
Attribute Range			High Moderate Low	High Moderate Low	High Moderate Low	High	High, Moderate Low	High, Moderate Low	Severe Significant Limited	High, Moderate Low	Very high High Moderate Low Very low	High, Medium Low	A to I	1 to11

Colour Ranges

On HGL derivative maps, it is suggested the following colours be used to define attribute ranges for each HGL.

Attribute	Range	Colour	RGB Colour Scheme
Overall Salinity Hazard	Very High	Red	255, 50, 0
	High	Orange	255, 150, 0
	Moderate	Yellow	255, 255, 150
	Low	Green	200,255, 150
	Very Low	Blue	200, 255, 255
Land Salinity	High	Red	255, 0, 0
Salt Export	Moderate	Yellow	255, 255, 0
Water Quality Impact	Low	Blue	0, 204, 255
Salt Availability			
Salt Store			
Likelihood of Salinity Occurrence			
Potential Impact of Salinity	Severe	Red	255, 0, 0
	Significant	Yellow	255, 255, 0
	Limited	Blue	0, 204, 255
Sodicity Hazard	High	Red	255, 0, 0

It should be noted that where hill-shading is used on the maps, the assigned attribute colours may appear to vary due to light and dark areas in the hill-shading.